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CORRESPONDENCE-STUDY

PRACTICAL COURSE IN CONCRETE

COURSE 430

ASSIGNMENT ...1...

MADISON
PUBLISHED BY THE UNIVERSITY
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UNIVERSITY EXTENSION DIVISION

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PRACTICAL COURSE IN CONCRETE

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PRACTICAL COURSE IN CONCRETE

PREPARED IN THE

EXTENSION DIVISION OF
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FIRST EDITION

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PRACTICAL COURSE IN CONCRETE

CHAPTER I

CONCRETE MATERIALS

1. Cement.—Portland cement is made by artificially mixing lime and clay in proper proportions, heating the mixture to the point of fusion, and then finely pulverizing the clinker. The materials from which Portland cement is manufactured vary with the locality, but Portland cement can be made anywhere by burning and grinding a proper mixture of carbonate of lime and a suitable clay.

The basic elements of Portland cement are silica, alumina, and lime. Ingredients such as iron, magnesia, alkalies, sulphuric acid, carbonic acid, and water also occur in varying quantities replacing some of the basic elements. The constituents should approximate the following limits:

	Per cent.
Silica	20 to 24
Alumina	5 to 9
Iron oxide	2 to 4
Lime	60 to 63.5
Magnesia	1 to 2
Sulphur trioxide	1.5

The essentials of Portland cement—namely: silica, alumina, and lime—are obtained from six different sources.

(1) Cement rock and limestone.
(2) Limestone and clay.
(3) Marl and clay.
(4) Chalk and clay.
(5) Blast-furnace slag and limestone.
(6) Alkali waste and clay.

Cement rock (argillaceous limestone, low in magnesia) and limestone are chiefly used in the Lehigh district and constitute the raw materials used for about two-thirds of the Portland cement manufactured in the United States.

In order to insure a satisfactory and uniform grade of cement, shipments for large or important work should be tested according to rules laid down by the American Society of Civil Engineers and the results should conform to the requirements of the standard specifications prepared by the American Society for Testing Materials. Copies of these publications may be obtained from the societies named.

Results of tests depend largely upon the method of testing and hence it is important that definite and uniform methods be employed. The kinds of tests usually made are as follows: (1) specific gravity; (2) fineness; (3) time of setting; (4) tensile strength of neat cement and of sand mortar; (5) soundness, or constancy of volume. A chemical analysis is also desirable on large work. The tests for soundness and strength are called primary tests, while the other tests are called secondary since they give only additional information which is of little value in itself.

Cement testing is a difficult process and should be entrusted only to experienced, well-qualified men. It is a well-known fact that the personal factor has considerable to do with the results obtained in cement testing and, on this account, there is a vast amount of dissatisfaction with the methods specified at the present time. Moreover, results by utterly untrained or careless operators are really worse than nothing and may be positively misleading. The comparative results by any one experienced observer, however, are generally consistent and are of value. From the above it should be recognized that, if cement tests are made, it is worth while to have them made well, even at a possible increase of expense.

The cement used in testing should be representative. Generally 1 bag in every 40 is sampled, or, in case of delivery in barrels, 1 barrel out of every ten. These small samples are usually mixed together to make an average sample. The whole is then taken to the testing laboratory, and there submitted to the standard tests. Usually 8 or 10 lb. of cement is taken from each carload for testing purposes. An average sample of a package may be obtained by means of a sampling auger (such as is used by butter or sugar inspectors) inserting it from top to center in bags, and from side to center in barrels. When sampling from barrels, a hole is made for the purpose in the center of one of the barrel staves midway between the heads.

Adulterations in Portland cement have generally been looked upon as detrimental to its quality, and the cement specifications in common use are of a character to exclude any grinding in of cheap material after calcination. Recent investigations have shown, however, that some forms of adulteration are possible without injury to the cement and in many cases may produce a decided improvement in every desired quality. The question at once arises—why should not specifications for Portland cement be changed so as to admit of such a practice, thus materially reducing the cost? The principal reason lies in the fact that with what is known at the present time, specifications permitting adulteration would be difficult to enforce and the results obtained with adulterated material would be uncertain. The specific gravity test of cement is mainly for the purpose of detecting adulteration such as clay, slaked lime, sand, ashes, natural cement, or products of natural rock-like ragstone or tufa. The specific gravity test, however, should be taken only as indicative and should be verified by other tests before rejecting a material which does not come up to standard. Chemical analysis serves as a valuable means of detecting adulteration, and also shows whether those elements believed to be harmful are present in too large quantities.

It is well known that fine grinding has a very great influence on the properties of the cement. The finer the grinding, the better the quality, since fine particles will more easily cover the sand grains, making mortar much stronger and allowing the use of a larger percentage of sand.

The time of setting of a cement may vary within wide limits and is no criterion of the quality, but it is important in the fact that it indicates whether or not it can be used advantageously in ordinary construction. A cement may set so quickly that it is worthless for use as a building material (since handling cement after it commences to set weakens it and causes it to disintegrate), or it may set so slowly that it will greatly delay the progress of the work. Long-standing cements absorb moisture from the air and lose their hydraulic property. A moderate amount of *seasoning* in weather-tight sheds, however, is often helpful to secure good results. Fresh cement contains small amounts of free or loosely combined lime which does not slake freely like ordinary lime and causes expansion, endangering the structure in which it is used in this condition. During the time of seasoning the free lime is changed to carbonate of lime and in this state the cement does not swell. Well-seasoned cement is generally lumpy, but the lumps are easily broken up. If, however, the cement has been subjected to excessive dampness, or has been wet, lumps will be formed which are hard and difficult to crush. Aside from the consideration of age, the conditions which accelerate the setting are: finely ground and lightly burned material, dry atmosphere, small amount of water used in gaging, and high temperature of both water and air.

There are two distinct stages in setting: (1) the initial set; and (2) the hard set. The best cements should be slow in taking the initial set but after that should harden rapidly. Portland cement should acquire the initial set in not less than 30 minutes, and hard set in not less than one hour nor more than 10 hours.

The object of testing cement in tension is to obtain some measure of the strength of the material in actual construction. In other words, tests of tensile strength are made primarily to determine whether the ingredients of the cement and the process of its manufacture are such that a continued and uniform hardening may be expected in the work, and whether it will have such strength when placed in mortar or concrete that it can be depended upon to withstand the strain placed upon it.

The small shapes made for testing are called *briquettes* and have a minimum cross-sectional area of 1 square inch, that is, at the place where they will break when tested. Tests are made with briquettes of neat cement and also with briquettes made of cement mortar (one part cement, three parts standard sand from Ottawa, Illinois). The neat cement tests measure directly its quality while the mortar tests are more nearly a true measure of its behavior under actual conditions.

It is customary to store the briquettes, immediately after making, in a damp atmosphere for 24 hours. They are then immersed in water until they are tested. This is done to secure uniformity of setting, and to prevent the drying out too quickly of the cement, thereby preventing shrinkage cracks which greatly reduce the strength.

Specifications for tensile strength of cement usually stipulate that the material must pass a minimum strength requirement at 7 and 28 days. This is required in order to determine the gain in strength between different dates of testing so that some idea may be obtained of the ultimate strength which the cement will obtain. A first-class cement, when tested, should give the values for tensile strength stated in the specifications of the American Society for Testing Materials.

W. Purves Taylor in "Practical Cement Testing" gives the following rules for accepting or rejecting material on the results of tensile tests:

"At 7 days: Reject on decidedly low sand strength. Hold for 28 days on low or excessively high neat strength, or a sand strength barely failing to pass requirements.

"At 28 days: Reject on failure in either neat or sand strengths. Reject on retrogression in sand strength, even if passing the 28-day requirements.

"Reject on retrogression in neat strength, if there is any other indication of poor quality, or if the 7-day test is low; otherwise accept.

"Accept if failing slightly in either neat or sand at 7 days and passing at 28 days."

It must be remembered that the sand test is the true criterion of strength, and no cement failing to pass this test should be accepted, even though the neat tests are satisfactory.

A cement to be of value must be perfectly sound; that is, it must remain constant in volume and not swell, disintegrate, or crumble. Excess of free or loosely combined lime which has not become sufficiently hydrated, excess of magnesia and alkalies, and coarse grinding, are all causes of unsoundness. Tests for soundness are among the most important to be made upon cements and should extend over considerable time to fully develop possible inherent defects. The usual way is to form small pats of neat cement about 3 inches in diameter, $\frac{1}{2}$ inch thick at the center and tapering to a thin edge. These pats should remain a definite time: (1) in air; (2) in water; and (3) in an atmosphere of steam above boiling water. To pass the soundness tests satisfactorily, the pats should remain firm and hard, and show no signs of cracking, distortion, or disintegration. The steam tests are what are called *accelerated* tests and are for the purpose of developing in a short time (five hours) those qualities which tend to destroy the strength and durability of a cement. In the present state of our knowledge it cannot be said that cement should necessarily be condemned simply for failure to pass the accelerated tests; nor can a cement be considered entirely satisfactory simply because it has passed these tests. The air and water tests are called *normal* tests and extend over a period of 28 days.

Full specifications similar to those of the American Society for Testing Materials are advisable for important work whether large or small. When purchasing by such specifications it may often be unnecessary actually to test the cement except for set, soundness and fineness, but the full specifications are recommended so that, if the cement does not work satisfactorily, it may be more carefully examined and unused portions rejected. Some large purchasers have apparatus for making complete cement tests in the field, but it is customary to have the tests made at some testing laboratory. In unimportant construction it is usually safe to use a first-class American Portland cement without testing.

Cement should be stored within a tight, weather-proof building, at least 8 inches away from the ground and an equal distance from any wall, so that free circulation of air may be obtained. In case the floor of the building is laid directly above the ground, it would be well to give the cement an additional 8-inch elevation by means of a false floor, so as to insure ventilation underneath. The cement should be stored in such a manner as to permit easy access for proper inspection and identification of each shipment. A period of at least 12 days should be allowed by the contractor for the inspection and necessary tests.

Where cement in bags is stored in high piles for long periods, there is often a slight tendency in the lower layers to harden, caused by the pressure above; this is known as *warehouse set.* Cement in this condition is in every way fit for service and can be re-conditioned by letting each sack drop on a solid surface before using the cement contained.

Cement may be obtained in cloth or paper bags, in bulk, and in barrels. Cloth bags are the containers most generally used since manufacturers will accept the empty bags if returned in good condition. The consumer, however, must prepay the freight when returning the empty bags to the mill. The cloth bag will stand transportation, and its size and shape make it convenient to handle. If properly cared for, it may be used over and over again. The following is quoted from *Concrete-Cement Age*, May, 1913:

"Wooden barrels are out of the question because of increased cost of packing the cement into them; the large initial cost of the barrel itself (35 cents to 40 cents each); the inconvenience in handling a package weighing 400 lb., especially on large work; the increased cost represented by freight on weight of each barrel (approximately 25 lb.); and the increased cost of the cement to the dealer and the user because the barrel cannot be returned. It will be seen, therefore, that the use of the wooden barrel would entail a direct additional tax on the dealer or the user—all items considered—of approximately 40 cents per barrel.

"Paper bags are used to a limited extent. They cost the manufacturer 10 cents per barrel (4 bags to a barrel), and the additional burden to the dealer and the user is represented by this 10 cents per barrel, plus the loss resulting from breakage in transportation and handling, which is large (probably 5 cents per barrel), and very annoying. The shippers will not be responsible for damage to paper bags and, on the whole, paper bags which cannot be saved or returned impose an additional and wholly unnecessary burden of approximately 15 cents per barrel—all items considered—on the ultimate consumer.

"If a cloth cement sack can be used eight times—as it may be if properly cared for and returned promptly when empty—the loss or burden imposed upon the ultimate consumer from the use of cloth sacks is 5 cents per barrel only, which is only $\frac{1}{3}$ the burden imposed by the use of paper bags, and $\frac{1}{8}$ the burden imposed by the use of wooden barrels.

"Cloth sacks, cheaper than those now used for carrying cement, are out of the question, because they are too frail and weak to stand transportation and protect the heavy weight of cement."

The following paper on *The Proper Care of Empty Cement Sacks* was presented before the Conference on Permanent and Sanitary Farm Improvements in August, 1913, by C. S. Fletcher of the Universal Portland Cement Co.:

"Every cement manufacturer in the United States ships most of his product in cloth sacks. This necessarily means a considerable outlay of capital as the sacks are not, by any means, received from a charitable institution. During the last year there were eighty-five million barrels of cement used in the United States. It is only fair to assume that seventy-five million barrels were shipped in cloth sacks. This represents $30,000,000 in hard, cold cash and I assure you that no company, cement or otherwise, would show any anxiety to assume such a gigantic loss.

Fig. 1—A sack of cement as it leaves the mill.

"When cement is sold, the price of the sack is included in the price of the cement. The cement company will re-purchase such sacks as are in good, sound, serviceable condition when delivered to mill, freight prepaid. As a great number of the sacks are so badly abused, the cement company is obliged to reject them. Such rejections are bound to bring about differences of opinion between the customer and the manufacturer. For instance: a man returns 400 sacks, naturally he wants $40.00 for them irrespective of their condition. When we are obliged to inform the shipper that we can only pay him for the good, sound sacks, which in this case amounts to $30.00, the fur begins to fly.


Fig. 2—A returned sack made useless through wetting.

"Not long ago the purchasing agent of a company which uses a lot of our cement, complained bitterly of the large number of rejections from their sack shipments. The situation grew so acute that the purchasing agent finally accepted our invitation to visit our plant and watch the count and inspection of his own individual sacks. When the next shipment reached our plant I notified this gentleman and we both started for the scene of action. As the bad sacks were being thrown aside the grieved party picked up a couple of them and asked me why we were throwing such sacks away. I suggested that he try and open some of them. He found this impossible as the fronts and backs of the sacks were cemented together. I asked him if he thought it possible to put ninety-five pounds of cement in such sacks. Then a great light dawned over the purchasing agent—'These are the sacks that we have been using for covering some newly laid concrete work.' If the men on the job had only realized that they were losing money by such work they would not have done it.

Fig. 3—A poorly mended cement sack showing the use of other material in making the patch. This sack was probably opened by the use of a shovel or knife.

"That purchasing agent was made to realize that cement sacks must be taken care of. It's the same way with the dealer, small or large; he must not expect to receive full credit from the cement company for abused sacks that he has bought back from his customers. It is up to every dealer to stand firmly on that part of the contract which reads 'Cement sacks will be paid for when returned in good, sound, serviceable condition.'

Fig. 4—Extreme care is taken in mending sacks at the Universal Plants. Before making the repair, the cloth is tested to insure sufficient strength, so that often a mended sack is better than one which has passed inspection without needing repair.

"It is hard to impress upon the ultimate cement consumer the fact that he should stand the sack loss. In the cement business the buyer has the edge; he has the privilege of returning the sacks and receiving the same price that he paid for them. Then, why should that man kick when a few sacks go to pieces on his hands?

"In order to show you how carelessly some people handle sacks I have brought along a few actual samples.

"The first one we have (Fig. 2) is a sack that has been allowed to get wet; you can see, the cloth is hard and rotten. Water is, without a doubt, as dangerous to cement sacks as a spider is to a fly. Just as soon as a sack becomes wet and begins to dry out, the cement dust in the fibers of the cloth hardens and leaves the sack in a weak and worthless condition.

"This sack (Fig. 3) has been badly repaired. If this customer had left the sack alone and sent it to our mill, he would be ten cents to the good. We would have repaired this sack, just as we do thousands of others, and paid full value for it.

"Here (Fig. 4) you see a sample of our repairing. This sack was badly torn when received by us but the cloth was in good sound shape. The repair was made and the sack is now just as good as the day it left the factory.

"The Universal Portland Cement Co. has spent a considerable amount of time and money every year educating customers to realize that a cement sack is worth ten cents and ought to be handled accordingly. I am pleased to say that our campaign has been productive of good results, but we still have a lot to do. One of the first lines of education taken up by us was the handling of sacks for shipment.

Fig. 5—Bundle of 50 cement sacks tied and tagged ready for shipment.

"This bundle (Fig. 5) that you see here contains fifty sacks tied with three stout ropes, tagged and ready for shipment. We have found from watching thousands of shipments received at our mill that this bundle stands up better than any other. It has several advantages over a larger bundle, chiefly because it can be handled much easier by freight handlers. It is altogether different with a bundle of one hundred sacks; such a bundle will be dragged over a rough floor where nails tear large holes in sacks, and very often this method has a tendency to loosen the bundle considerably. The chances, therefore, of all the sacks in such a bundle reaching destination are very slim.

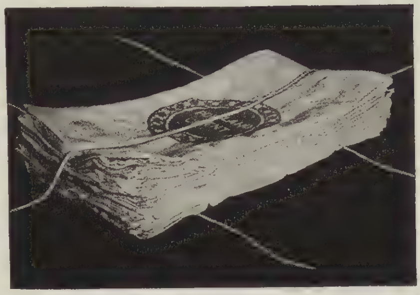

Fig. 6—A bundle of 50 cement sacks laid out flat with 2 ropes 40 inches long under the pile, with longer rope of about 8 ft. resting on top.

"Some time ago the railroads put through certain regulations governing the shipment of returned empty cement sacks. In order to familiarize our trade with these regulations the illustrated sack placard that you see here was sent broadcast to every customer on our books. In Fig. 6 you see fifty sacks laid out flat with two ropes 40 inches long under the pile and a longer rope about 8 feet long resting on top of the pile. In Fig. 7 the two short ropes have been brought over the pile of sacks and tied tightly. The last figure shows the bundle turned over and the long rope brought around it and crossed in the middle of the bundle.

Fig. 7—The first operation in bundling is to bring two of the ropes over the pile, as shown, tying tightly.

"We leave very little room for a man to say that he does not know

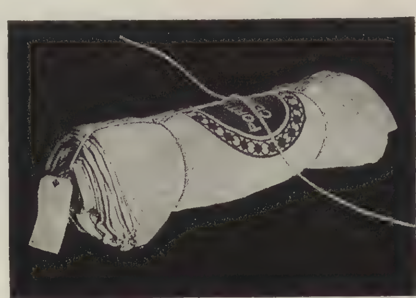

Fig. 8—After the short ropes have been tied the bundle is turned over and the long rope brought around and crossed in the middle of the bundle, engaging first the shorter ropes.

how to ship sacks. As already stated, each customer has received one of these sack placards, and a supply of linen tags is sent out in every car that leaves our mill. Furthermore, we have made arrangements with all railroads that a sack placard is to be placed in each and every railroad freight house, throughout the country, so that if a man asks his agent how to ship sacks the agent will know what to tell him."

Within the past year or two considerable cement has been shipped in bulk to cement-product factories and to construction jobs adjacent to railroad tracks. Much economy has resulted from the saving in labor, and from the elimination of package losses and expense. There seems to be no difficulty in shipping bulk cement in tight box cars and this method will undoubtedly become more popular in the near future.

2. **Aggregates.**—Present-day success in the use of concrete is not due to any particular "discovery" but is the result of consistent, scientific study and investigation of the component materials.

As ordinarily employed, the term "aggregates" includes not only gravel or stone (the coarse material used) but also the sand, or fine material, which is mixed with the cement to form either mortar or concrete. Fine aggregate is defined as any suitable material that will pass a No. 4 sieve (screen having four meshes to the linear inch) and includes sand, stone screenings, crushed slag, etc. By coarse aggregate is meant any suitable material, such as crushed stone and gravel, that is retained on a No. 4 sieve. Coarse aggregate over $1\frac{1}{4}$ inches in largest dimensions is not generally used.

The strength of concrete can never be greater than that of the materials used as aggregate. Nothing is more conducive to unsatisfactory results in concrete work than poor aggregates. The quality of the cement, methods of mixing, the proportions used, and the amount of water added, also the method of depositing concrete, all have their effect upon the density and strength of concrete but even with the most careful attention given to these details, good results are impossible without good aggregates.

The fact that the aggregates *seem* of good quality yet may be proved *totally unsuitable*, shows that study and careful tests are necessary if the best results are to be obtained. The idea that the strength of concrete depends entirely upon the cement and that only a superficial examination of aggregates is necessary, is altogether too prevalent. The man who understands his aggregates, grades them properly, sees that they are washed, if necessary, then mixes them in proportions determined by thorough testing, study, or actual experience, is the one who will make the best concrete.

In the selection and use of sand, more precautions are necessary than for the coarser aggregate, due to its physical condition, and a wider variation in properties. A knowledge of these properties, and of the method of analysis to determine the suitability of sand for use in mortar and concrete, may be easily applied to an analysis of the coarse aggregate. (Stone screenings, broken stone, and gravel will be discussed only where their properties and the methods of examining them differ from those of sand.)

Geologists classify rock in one of two large groups:

1. Igneous.
2. Sedimentary.

Igneous rocks are those which have been formed by the cooling of fused material. The original crust of the earth was formed entirely of igneous rock, but it is highly improbable that any of this original crust is now exposed at the earth's surface.

Igneous rocks are classified either as massive or laminated, according to their structure. The massive igneous rocks are those which have been solidified, undisturbed, from a fused state and which have not been subsequently subjected to severe external stresses. When the rock was subjected to external pressure during or after cooling, a laminated structure seems to have resulted, with the component minerals arranged in more or less definite alternating bands. Most *granites* and all *trap rock* belong to the first class, while rocks of the second class are termed gneisses.

Sedimentary rocks are those derived from the breaking up or disintegration of preëxisting strata, the material so obtained being carried, usually in suspension or solution, to some point where it is redeposited as a bed of sand, clay or calcareous material, such as shells, marls, etc. Subsequently, this loosely-deposited material may become consolidated and compacted by pressure or other agencies, the result being the formation of sandstone, shale, and slate or limestones, dolomites, and marbles.

Sedimentary rocks may be classified on a combined chemical and physical basis, distinguished by the material of which they are chiefly composed, as:

1. Silicious sedimentary or sandstone, and conglomerates.
2. Argillaceous or clayey rocks, such as shales and slates.
3. Calcareous rocks, namely marble, compact limestone, granular limestone and magnesian limestone, or dolomites.

The materials commonly used as coarse concrete aggregate in different places throughout the United States are the sedimentary rocks, which may be grouped into three classes on the basis of origin.

1. Glacial deposits.
2. Costal plain deposits.
3. Stream deposits.

All of these deposits contain more or less silt, clay, loam or other finely divided impurities.

The gravel beds of the glacial drifts furnish excellent material for concrete. Baker, in *Roads and Pavements*, says: "Glacial gravel exists in considerable quantities in western Pennslyvania, in the greater part of Ohio, in northern Indiana, and in Illinois, and to some extent in several of the states of the southwest. There are large areas of this gravel in Wisconsin, Minnesota and Iowa."

Sands differ, not only in chemical and mineralogical composition but in physical condition. They often contain many impurities, and the methods for determining the presence of these impurities, as well as their effects, should be known. Many of these impurities impair the hardening properties of cement, and hence the strength of the resulting concrete. Much has been written relative to the effect of clay upon concrete and many contradictory opinions have been advanced. Engineers are, however, fairly in accord on certain conclusions. When clay exists as a coating on the particles of sand aggregate, it is undoubtedly injurious, as proper adhesion between the cement and the sand surfaces is then prevented. When, however, clay of a silicious nature, in the form of separate particles, exists to a small extent throughout the mass of aggregate, it appears to cause no serious harm in many kinds of concrete work. Although clay in this form acts as an adulterant, some writers have held that from 5 to 10 per cent may be admitted without seriously reducing the strength of the concrete. Their opinions, however, are based largely on the results of tensile-strength tests on relatively dry mixtures. It is doubtful whether under field conditions, or even in large compression-test specimens made up in the laboratory, these results would be obtained. An excess of clay tends to lead one into believing that the concrete contains an excess of cement rather than a shortage. The only advantage that can be claimed for the presence of clay is, that it increases the density of the concrete by filling some of the voids.

The presence of clay in sand may be detected by the well-known method of rubbing the material between the hands. If clean, the sand should not adhere to or discolor the hands. Also a small quantity of the sand may be stirred or shaken in a tumbler or bottle of water, when the presence of clay will at once be shown by a characteristic cloudiness of the water. Since the clay remains longer in suspension than the sand, it will separate and settle later in a layer on top.

A coating of vegetable matter on sand grains appears not only to prevent the cement from adhering but to affect it chemically. Frequently, a quantity of vegetable matter so small that it can not be detected by the eye and is only slightly disclosed in chemical tests, may prevent the mortar from reaching any appreciable strength. Concrete made with such sand usually hardens so slowly that the results are questionable and its use is prohibited. Other impurities such as acids, alkalies, or oils in the sand or mixing water, usually make trouble.

The usual way of determining the quality of sand is to make up briquettes in the proportions of one part cement to three parts of the sand to be tested, and compare the results with the strength of a mortar made with the same cement and standard Ottawa sand in like proportions and of standard consistency.

The presence of moisture in sand may make proper mixing with other materials somewhat difficult, as a uniform distribution of cement in the mortar is hard to obtain.

General Requirements

The quality of concrete is affected by

1. The hardness, or crushing strength, of the aggregates.
2. Their durability or resistance to weather.
3. Grading, or maximum and relative sizes, of particles.
4. Cleanliness, or freedom from foreign materials.
5. The shape and nature of the surface of the particles.

Hardness.—The hardness of the material grows in importance with the age of the concrete. Because of the rounded surface of the aggregate, gravel concrete one month old may be weaker than concrete made with comparatively soft broken stones; but when one year old, it may surpass in strength the broken stone concrete, because as the cement becomes harder and the bond firmer, the resistance of the aggregate to stress, becomes a more important factor.

The grains should offer at least as high a resistance to crushing as does the cement after attaining its maximum strength. In comparing sands of the same kind, those having the highest specific gravity are likely as a rule to be the strongest. This applies in a general way to the comparison of different kinds of rock also.

Value of Different Rocks.—Different rocks of the same class vary so widely in texture and strength that it is impossible to give definitely their relative values as aggregate. However, a comparison of a large number of tests of concrete made with broken stone from different kinds of rock material indicates that its value as an aggregate is largely governed by the actual strength of the stone itself, the hardest stone producing the strongest concrete.

Comparative tests discussed by various writers indicate that, in the order of their value for concrete, the different materials stand approximately as follows:

1. Granite.
2. Trap rock.
3. Gravel.
4. Marble.
5. Limestone.
6. Slag.
7. Sandstone.

The grading—that is, the relative size and quantity of the particles of an aggregate—determines in a large measure the density of the mass, which greatly affects the quality of the concrete. A coarse, well-graded aggregate produces a denser and stronger concrete or mortar. A sufficient quantity of fine grains is valuable in grading the material and reducing the voids, but an excess has a tendency to diminish the compression strength considerably.

Weights and Voids.—A high unit weight of material and a corresponding low percentage of voids are indications of coarseness and good grading of particles. However, the impossibility of establishing uniformity of weight and measurement due to different percentages of moisture and different methods of handling, make these results merely general guides that seldom can be taken as positive indications of true relative values. This is especially true of the fine aggregates in which percentages of voids increase and weights decrease with the addition of moisture up to about 6 per cent.

Maximum Size.—Within reasonable limits the strength of concrete increases with the size of stones. For mass concrete, the practical maximum size is $2\frac{1}{2}$ to 3 inches. In thin reinforced structures, such as floors and walls, the size must be such as can be worked readily about the reinforcing metal, and $1\frac{1}{4}$-inch aggregate is generally the maximum.

Cleanliness.—As stated, the particles of rock should be free from dirt and dust, and should not be used when even partly covered with clay; such impurities prevent the cement from obtaining a bond on the surface of the particles and often contain materials which retard the hardening of the mortar or concrete and prevent it from acquiring normal strength within a reasonable length of time.

An excess of clay or dirt in any form also affects the color of the concrete when hardened, and necessitates more thorough mixing.

Shape of Particles.—The shape of the rock particles influences the strength of the mortar or concrete. Flat particles pack loosely and generally are inferior to those of cubical fracture.

ANALYSIS.

The chief value of an analysis of any sand results from the comparison of its various properties with those of other sand tested under similar conditions, and recognized as of a good quality.

Classification.—The sands in common use as aggregate throughout the United States are sedimentary, hence the classification can usually be confined to the degree of consolidation and the kind of material, on the basis of whether its formation is chiefly silicious or calcareous. Hardness and texture are ready aids in these determinations, which may be conducted in an elementary manner.

The natural sands are usually silicious, but they vary in degree of consolidation, which determines in a large measure the crushing strength and durability of the concrete. Durability is also dependent upon the nature and amount of impurities present, as feldspar, mica metal oxide, etc. Such impurities account largely for the variegated coloring of sand grains.

Specific Gravity.—As sands, or rocks of the same kind having the highest specific gravity are likely to be strongest, a determination of the specific gravity of different sands is valuable, since it is a ready indication of the nature and hardness of the material. As a rule sand having the highest specific gravity, other things being equal, will give the best results.

The specific gravity of a material is determined by dividing its weight by the weight of the water which it displaces when immersed. Take a convenient amount of sand, screen it through a ¼-inch screen, dry, and weigh. Then place some water in a glass graduate, read the height of the water, add the sand, and again read the height of the water. The difference in readings will be the weight of water displaced by the sand. Divide this weight of water into the weight of the sample of sand. The result will be the specific gravity of the sand. (For detailed methods of testing sand and cement-sand mortar, Bulletin No. 33 of the United States Bureau of Standards should be referred to.)

Determinations Necessary.—Physical Analysis: The determinations necessary for a good physical analysis of sand are:

1. Strength and density in mortar.
2. Gradation and effective size of grains.
3. Cleanliness, including per cent and nature of silt.
4. Percentage of voids.

Density.—In the study of sands, a determination of their density is important as regards both quality and economy. Other physical conditions being equal, the sand which produces the smallest volume of plastic mortar when mixed with cement in the required proportions, makes the strongest and least permeable mortar, and the densest mortar will be the strongest. This requires that the sand be graded from coarse to fine, the coarser particles predominating. (The question of determining density will be discussed in Chapter II on Proportioning.)

Gradation and Effective Size.—Sand made up of coarse grains will produce a greater strength in mortar than that made up of fine grains, because it presents a more compact mass as well as a smaller amount of surface area to cover with cement, and usually a smaller percentage of voids. A fine sand requires more thorough mixing than coarse sand in order to get a proper distribution of cement.

The size of sand grains is so important that it is often profitable to ship a coarse sand a considerable distance rather than use a local fine sand. Feret, the French authority, computed that it was more economical to use coarse instead of fine sand, even though the cost is several times as great. It does not follow, however, that because coarse particles have the smallest area per unit of volume, the aggregate should all be large. Particles of the same size form a volume having a larger percentage of voids than if graded in size, hence require a larger proportion of cement to produce the maximum strength.

Granulometric Composition.—The determination of the granulometric composition or mechanical analysis of sand is made in order to study its properties and to judge of its value compared with other sands, and sometimes to enable regrading its grains so that a denser mass may be secured.

That the strength, quality, and value of a sand may be indicated by ascertaining whether the majority of its particles are coarse, medium, or fine, has been generally established, and it is also important to determine the relative degree of coarseness and fineness.

The percentages of different size grains are frequently determined by a mechanical analysis. The sample is first screened through a number of sieves of successive sizes, and the percentage by weight retained on each, recorded.

For this work the following sieves are recommended:

Commercial No. of Sieve

4	30	80
10	40	100
20	50	200

A standard sieve is made of woven brass wire, set into a hard brass frame, 8 inches in diameter and 2¼ inches deep. These sieves are described by numbers corresponding approximately to the number of meshes per linear inch.

All material referred to as sand must pass a No. 4 sieve. Not more than twenty (20) per cent should pass a sieve having fifty (50) meshes per linear inch, and not more than five (5) per cent should pass a sieve having one hundred (100) meshes per linear inch.

The tabulated results showing the percentages by weight retained on the different sieves form a valuable basis for a study of the effective sizes of grains, and for comparison with other sands whose value in mortar or concrete has already been determined.

Cleanliness.—The effect of dirty sand is dependent upon the quantity and nature of the impurities and the form and manner in which they are present. The manner in which silt is contained in sand may be determined by inspection. The silt in a sand is that material which in solution and in suspension is carried away in wash water so applied as not to remove the small grains of sand. This amount may be ascertained by determining either the amount of substance contained in the wash water, or the amount of loss sustained by the sand through washing. The latter method is more generally used.

If the silt is vegetable matter in a gelatinous or viscous state, forming a colloidal covering over the surface of the sand grains, its presence may be determined by immersing the material in a dilute solution of sulphuric or hydrochloric acid and comparing the strength of cement mortar made from the sand before and after immersion.

The following paper on *Presence of Dirt in Concrete Aggregates*, by Mr. C. D. Franks of Chicago, was presented before the Conference on Permanent and Sanitary Farm Improvements in August, 1913.

"It is well known that screened and well-graded aggregate is a necessity for making good concrete. However, no matter how well your material may be graded, if it contains foreign material, such as silt, loam, or clay, the effect of good grading is partially lost. The presence of silt or dirt in sand or gravel materially affects the success of your concrete work.

"Some time ago my attention was called to the construction of a concrete foundation wall. This particular wall had been constructed of a $1:2\frac{1}{2}:5$ mixture—that is, for every sack of cement, $2\frac{1}{2}$ cubic feet of sand, passing a $\frac{1}{4}$ inch screen, and 5 cubic feet of gravel from $\frac{1}{4}$ inch to 2 inches in size were used. The sand had been screened from the gravel and the material properly proportioned, mixed with cement and water and placed in the forms. About 7 days after the wall had been completed, the forms were removed. The outside surface of the foundation wall appeared very hard, but when the forms had been entirely removed the wall partially collapsed and an examination of the interior of the concrete showed that it was very weak and porous. It was a natural thing for the contractor to place the blame on the material which had least to do with the failure, the cement. However, the engineer who had superintended the construction of the wall became suspicious and began an investigation to determine the true cause of failure. His investigations showed that the thin film coating which appeared on the outside and inside of the foundation wall was silt. In the concrete this same silt had coated the particles of sand and gravel, and as a natural consequence prevented the cement from adhering to the surfaces, resulting in weak concrete and the failure of the wall.

"The examination of sand for silt or for foreign material really belongs to the laboratory properly equipped for making analyses. The examination or analysis which is sometimes performed on the job, does not show accurate results. As a rule, the samples of sand or gravel are given a physical analysis and, in the case of the sand, a chemical analysis, in order to give the contractor or engineer a thorough knowledge of the quality of the material that he is to use. Such laboratory methods can not be adopted, however, by the ordinary contractor or farmer who wishes to do good concrete work, and his work is just as important to him as the construction of large buildings. I would suggest, then, when you are selecting material for your concrete work, that you investigate thoroughly the manner in which the material comes from the pit. The strippings of the pit (that is, the clay or loam above the sand and gravel, tree roots and all foreign material) should be removed carefully. Often a close examination of the gravel bank will give a fair idea as to the quality of the material in question. If you pick up handfuls of sand and gravel from various parts of the pit and allow it to dribble slowly through your fingers, the presence of dirt or silt, evenly divided, will make your fingers and hands feel soapy or slippery. If that condition exists, you can well look upon the quality of the material with suspicion, for it probably contains material which should be removed to insure the success of your concrete work.

"If you are doing concrete work, it is not absolutely necessary to have extensive laboratory apparatus to determine in a fair way the quality of the sand and gravel. Take a gallon glass jar, for instance, and select representative samples from the pit—that is, a sample that represents the average material as it ordinarily comes out in wagon loads. Put this sample in the jar as carefully as possible and add to the sample an amount of water twice the volume of the material. Shake it up thoroughly three or four times, allowing the material to settle after each shaking. After a short time the dirt or silt which is liable to affect the strength of your concrete will appear in a layer on top of the clean sand and gravel.

"You can determine quite accurately the percentage of silt in a certain amount of sand and gravel by the use of a graduated glass cylinder with a capacity of 100 cubic centimeters. Fill this half full with the material, shaking down well until it has been thoroughly compacted. Then fill the interstices of the sand or gravel with water, shake it well, and then fill again. The shaking will give the air a chance to escape from the sand. Shake the cylinder and fill with water until you have a volume of 100 cubic centimeters. When the material has been allowed to settle the amount of fine material may be read. There will be a distinct division line between the dirt or silt and the clean sand and gravel. Multiply the amount read by 2 and you will have the percentage of dirt and silt contained in that sample of sand. Material containing over 2 or 3 per cent of dirt or silt should be washed because we have no way of determining in the field the character of this particular silt or dirt.

"It is not always possible for the farmer or the small contractor to equip himself with a screening and washing plant. However, there are methods which he can use economically and wash his material. For example, I have found by past experience that an ordinary $\frac{3}{8}$-inch screen set at 45 degrees to the horizontal may be used as part of a washing plant. A stream of water of sufficient strength coming over the top of the screen between two sheets of metal and spreading into a spray, will wash the material thrown on to the screen free from dirt. The gravel will roll off the end of the screen, while the sand will be carried through with the water. If a baffle board is constructed and drainage provided beneath the screen, the water will drain away with a considerable portion of the dirt in suspension.

"The ordinary method of determining the percentage of silt in the laboratory is by taking a certain weight of sand, dried at the temperature of the laboratory, placing this material in a glass provided for the admission of water, from the bottom under pressure, the pressure being reduced so that the running water will wash the dirt from the sand but will not carry the finer particles of sand away over the sides of the glass. The water is allowed to pass through the material until it runs clean and clear over the sides of the glass. The sample is removed then from the glass and dried. From the difference in weight of the sample before and after washing the percentage of dirt or silt may be determined.

"There are several conditions under which the silt may exist in concrete aggregate, and upon these conditions depend whether or not the silt or foreign material will be detrimental to the concrete when it is mixed and placed in the forms. If the clay for the sample exists in a finely powdered form, well distributed through the mass, it will act simply as an adulterant, that is, if it does not ball up in the mixer and adhere to the particles of sand and gravel during the mixing. If this latter condition prevails then the cement has no chance to adhere to the surface of the particles. On the other hand, if silt or clay exists in layers or chunks throughout the pit, then you will have considerable trouble because from this condition weak places and cracks will in all probability develop in your concrete work. These conditions we desire to avoid in all concrete work. Even though the silt or clay is distributed, it is best to wash the sand and gravel free of this material.

"The strength of concrete depends upon the strength of the material you are using. Comparison tests on blocks of concrete have shown, however, that silt or clay, coating the particles of sand and gravel, reduce the compressive strength of the concrete to a great extent. Test pieces made up of good, clean material, at the age of 28 days, when broken under a testing machine, will, as a rule, show a large percentage of broken particles. On the other hand, compressive test specimens made of dirty aggregate, using the same amount of cement and tested at the same age, will show the particles pulling out from the bed of mortar around them and less strength.

"There is one other thing which should be mentioned in connection with concrete work, that is, the effect of finely powdered dust which is present in limestone screenings. Experiments have shown that this dust, unless removed from the coarser particles of screenings and broken stone, causes approximately the same effect upon the strength of concrete as does the presence of silt or clay. It is essential that this dust be removed by screening and washing practically in the same manner that silt or other foreign material is removed from sand and gravel."

Voids.—Voids are air spaces between the grains and are usually referred to as a percentage of the whole. A sand consisting of grains all uniform in size, will present the maximum of voids. This can be illustrated as follows: Perfect spheres of equal size piled in the most compact manner leave, theoretically, but 26 per cent of voids. The only requirement is that the spheres be of equal size. Suppose, now, that the spaces between such a pile of equal sized spheres were filled with other perfect spheres of diameter just sufficient to touch the larger spheres, the voids in the total included mass would be reduced theoretically to 20 per cent; and should this be followed up with smaller spheres, the air spaces or voids could be reduced sufficiently to make the mass water-tight. The shape of the particles also affects the percentage of voids. Round particles compact more readily and firmly, and with less difficulty, than angular particles.

Conclusion

The scope of concrete work has become so great that it demands a nation-wide study of aggregates. But such study alone will not solve all the problems and insure good work in the future. It will, however, serve to give an idea of the relative merits of the various aggregates available. We now have standard specifications which demand certain requirements from the cement manufacturers. How much more do we need standard specifications for the selection of concrete aggregates. The preceding paragraphs have in a brief way, given you some idea of the properties required in good aggregate, which are, briefly: good grading, cleanliness, and durability. Therefore, with good aggregates, standard Portland cement, and careful and efficient workmanship, good concrete can easily be obtained.

Examination Questions

1. What is the proper method of storing cement?
2. What are the reasons for making tests of cement for set, soundness, and fineness?
3. What does the term *aggregate* include?
4. How may the presence of clay in sand be detected?
5. Name seven kinds of materials in the order of their values for concrete aggregate.
6. Which has the greater percentage of voids, sand of uniform or of graded sizes?
7. Name the properties required in good aggregate.

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CHAPTER II

PROPORTIONING

3. **Theory of Proportioning.**—In order to comprehend the importance of correctly proportioning the ingredients entering into the composition of concrete we must in the beginning obtain a correct idea of the theory of the material we propose to manufacture.

The aggregates consisting of sand and gravel or broken stone are wholly inert, until combined with Portland cement. Consequently it is of prime importance that every piece of coarse aggregate be thoroughly surrounded with sand-cement mortar, and that every grain of sand be enclosed in a film of neat cement. In so far as actual practice departs from this fundamental principle, just so far will the bonding be defective.

The second important principle of concrete composition is that voids shall be eliminated by such gradation of materials that the spaces between larger pieces of the coarse aggregate will be occupied by smaller pieces, and the spaces between these will in turn be filled by sand until, in a perfectly proportioned mixture, there will remain only such voids as will be taken up by the cement solution when the concrete is finally compacted in the place of its ultimate use. The absolute elimination of voids is an ideal condition, hence it is essential to use every means in our power toward approaching the perfection suggested. The more nearly we approximate the theoretical possibility, the more successful we shall be in actual practice.

4. **Object of Proportioning.**—Both strength and density in finished concrete construction are dependent upon careful proportioning. A very porous concrete may under certain conditions of manufacture be stronger than a very dense concrete which is lacking in cement or in coarse aggregate. Hence, we observe work disintegrate after two or three years, and upon examining a fracture find that the concrete has no large voids but is composed of fine sand

with little or no coarse aggregate. Such material may appear dense, but hardly deserves to be called concrete.

On the other hand, remarkable instances of strength developed in porous concrete may be observed where the coarse aggregate was fairly well graded and but little sand used. This practice is not recommended because the working conditions might not be identical, and a concrete possessing a large percentage of voids will not be watertight. The point is mentioned merely to emphasize the fact that coarse aggregate and cement give strength to concrete. Sand increases the density.

Impermeability, or resistance to the passage of water, is one of the most prominent characteristics of good concrete and is absolutely dependent upon the elimination of voids, which results only from correct proportioning of ingredients. A porous concrete is never watertight. Quite a number of processes for waterproofing have been suggested, some like soap and alum or the "Sylvester Process" are public property, while others are either secret formulas or process patents. Some consist of incorporating compounds in the concrete at the time of mixing, and others of applying compounds to the exterior or interior of the work after completion. If the concrete is properly proportioned, there is no reason for using any extraneous waterproofing medium.

In reinforced-concrete work a satisfactory bond between the steel and concrete can be obtained only by such careful proportioning as will insure a concrete practically free from voids. This does not mean merely slushing in water enough to fill spaces between aggregate surrounding rods or other reinforcement. Surplus water will disappear by evaporation, leaving cavities adjacent to the reinforcement, and when a failure occurs rods will be found pulled out of porous concrete which lacked the bond that saves structures.

5. Methods of Proportioning.—The following methods of proportioning concrete are in general use

1. Arbitrary selection of proportions.
2. Void determination.
3. Proportioning by trial mixtures.

Proportioning by Arbitrary Selection.—As many users of concrete do not wish to take the trouble to test their own materials, it is customary for them to use the proportions which have been found to produce satisfactory results under average conditions. These are one part of cement, two and one-half parts of sand, and four parts of coarse aggregate (expressed 1:2½:4) for most classes of construction. In the manufacture of products large enough to use aggregate exceeding one inch in greatest dimension, the proportion of coarse aggregate may be increased accordingly. Conversely, where a fine texture is desired for ornamental purposes, the proportion of cement must be increased reaching its maximum in 1:1½ trowelled surfaces. The following table gives the proportions recommended for various classes of work:

Concrete

A 1:2:3 mixture for:
- One course concrete highway, street and barnyard pavements.
- One course floors and walks.
- Roofs.
- Fence Posts and for sills and lintels without mortar surface.
- Water troughs and tanks.

A 1:2:4 mixture for:
- Reinforced concrete floors, beams and columns, large engine foundations.
- Work subject to vibration.

A 1:2½:4 mixture for:
- Building walls above foundation.
- Silo walls.
- Base of two course street and highway pavements.
- Backing of concrete block and similar cement products.

A 1:3:5 mixture for:
- Basement walls and foundations.
- Small engine foundations.
- Base of sidewalks and two course floors.
- Mass concrete footings, etc.

Mortar

1:1½ mixture for:
- Wearing course of two course floors.

1:2 mixture for:
- Scratch coat of exterior plaster.
- Facing blocks and similar cement products.
- Wearing course of two-course walks, street and highway pavements.

1:2½ mixture for:

Finish coat of exterior plaster.

Fence posts, when coarse aggregate is not used.

1:3 mixture for:

Concrete blocks when coarse aggregate is not used.

Cement drain tile, when coarse aggregate is not used.

When proportions of the ingredients of a concrete are specified, the specifications should state whether the cement shall be measured loose or as packed in bags and barrels. The reason for this is clear when it is considered that loose cement occupies about 30 per cent more volume than packed cement. The usual method is to specify the barrel of packed cement as the unit, and to assign it some definite volume—the sand and stone to be measured loose.

A barrel of Portland cement weighs 376 lb., not including the barrel, and a bag of Portland cement weighs 94 lb.; in other words, there are four bags to a barrel. For convenience the bag of cement is usually assumed as one cubic foot in proportioning but is actually somewhat less, depending on the brand. When a barrel is assumed to contain 3.8 cu. ft., as is sometimes done, then 100 lb. of cement can be considered as one cubic foot.

It should be stated here that the common rule of thumb method of proportioning concrete may cause wide discrepancies because of the variation in the character of the ingredients. In fact, arbitrary selection should never be permitted except where the work is not expensive or important enough to warrant special proportioning of the materials and grading of the aggregates.

If arbitrary proportioning is decided upon, the best method to follow is to proportion the cement to sand by judgment in accordance with the character of the construction, to adopt (as a trial) twice as much stone as sand by volume, and then to vary this proportion using as much of the coarse aggregate as possible without producing noticeable voids or stone pockets in the concrete. In cases where the coarse material contains a great many small particles, the proportion of sand should be tried at somewhat less than one-half the volume of stone.

Experience in the handling of concrete enables one to judge readily whether the mortar is deficient or not. With too little sand, stone pockets are apt to occur on the surfaces, and it is difficult to fill all the voids in the stone; with too much sand, a harsh working of the concrete will be noticed or an excess of mortar will rise to the top when placing.

Proportioning by Void Determination.—There are four distinct methods of proportioning concrete by the determination of voids:

(a) Finding the voids in the stone and in the sand, and then proportioning the materials so that the volume of sand is equivalent to the volume of voids in the stone and so that the volume of cement is slightly in excess of the voids in the sand. (The excess of cement is provided on account of inaccuracies in the void method of porportioning.)

(b) Finding the voids in the stone, and, after selecting the proportions of cement to sand by test or by judgment, proportioning the mortar to the stone so that the volume of mortar is slightly in excess of the voids in the stone.

(c) Mixing the sand and stone and providing such a proportion of cement that the paste will slightly more than fill the voids in the mixed aggregate.

(d) Making trial mixtures of dry materials in different proportions to determine the mixture giving the smallest percentage of voids, and then adding an arbitrary percentage of cement, or one based on the voids in the mixed aggregate.

Proportioning by the determination of voids is little (if any) better than the proportioning by arbitrary assignment. In the first place, the percentage of voids in sand is greatly affected by even a small percentage of moisture. When sand is moistened, a film of water coats each particle of sand and separates it by surface tension from the grains surrounding it. Fine sand, having a larger number of grains, and consequently, more surface area, is more increased in bulk by the addition of water than coarse sand. Again, the volume of water required in mixing actually occupies space in the resulting concrete and not only every cement but also every sand has a different and definite percentage of water necessary to bring it to what may be called normal consistency. Voids in absolutely dry sand are certainly no criterion of its qualities for concrete, while a moist sand will give different results on different days.

Inaccuracy in proportioning by void determination is also due in part to the difference in the compactness of the materials under varied methods of handling, and to the fact that many grains of the sand are too coarse to enter the voids of the stone and consequently thrust apart the particles of the large aggregate. Many of the voids in the sand are also too small for the grains of cement to fit into them without expanding the volume.

Percentage of voids is usually determined by finding the specific gravity of the solid particles, weighing a known

Fig. 9.—The impossibility of obtaining proper and uniform proportion from this average gravel bank is self evident.

volume of the aggregate and computing therefrom the percentage of voids. The voids in sand will average about 33 per cent, while in stone or gravel the open space averages in the neighborhood of 45 per cent.

Proportioning by Trial Mixtures.—The fact that the densest concrete is the strongest and most impermeable makes possible a convenient and accurate method of proportioning concrete and of determining the relative value of different aggregates. Mr. William B. Fuller describes the method as follows:

"Procure a piece or steel pipe 8 to 12 in. in diameter and a foot long and close off one end; also obtain an accurate weighing scale. Weigh out any proportions selected at random, of cement, sand, and stone, and of such quantity as will fill the pipe about three-quarters full, and mix thoroughly with water on an impervious platform, such as a sheet of iron; then, standing the pipe on end, put all the concrete in the pipe, tamping it thoroughly, and when all is in, measure and record the depth of the concrete in the pipe. Now throw this concrete away, clean the pipe and tools and make up another batch with the total weight of cement, sand, and stone the same as before but with the proportions of the sand to the stone slightly different. Mix and place as before and measure and record the depth in the pipe, and if the depth in the pipe is less and the concrete still looks nice and works well, this is a better mixture than the first. Continue trying in this way until the proportion has been found which will give the least depth in the pipe. This simply shows that the same amount of materials is being compacted into a smaller space and that, consequently, the concrete is more dense. Of course, exactly similar materials must be used as are to be used on the work, and after having in this way decided on the proportions to be used on the work it is desirable to make such trials several times while the work is in progress, to be sure there is no great change in materials, or, if there is any change, to determine the corresponding change in the proportions.

"The above-described method of obtaining proportions does not take very much time, is not difficult, and a little trouble taken in this way will often be productive of very important results over the guess method of deciding proportions so universally prevalent.

"A person interested in this method of proportioning will find on trial that other sands and stones available in the vicinity will give other depths in the pipe, and it is probable that by looking around and obtaining the best available materials the strength of the concrete obtainable will be very materially increased."

6. Sizing Materials.—Unless sand and gravel are purchased separately, it will be necessary to separate them by screening to arbitrary sizes before proportioning. If, for instance, it is proposed to use bank gravel varying in size from fine sand up to small boulders two screens should be used. The first should reject everything exceeding the maximum size of aggregate suitable for the work, this varying from $\frac{3}{4}$ inch, for fence posts and block, up to 2 inches for foundations and other work of large cross section. The general rule for walls is that the largest size of aggregate shall not exceed, in its greatest diameter, one-half the thickness of the wall. The second screen should in all cases be of $\frac{1}{4}$-inch mesh, the particles retained upon it to be regarded as coarse aggregate, and those passing it as fine aggregate, or sand.

The following is taken from a paper on *The Selection and Proportioning of Concrete Aggregates* by Mr. C. K. Arp of Chicago, presented at the Conference on Permanent and Sanitary Farm Improvements in August, 1913:

"Many are of the opinion that when a 1:2:4 mixture is required, it is possible to obtain this by taking one part

Fig. 10.—In some parts of the gravel bank the material consists almost entirely of coarse particles.

of cement and 6 parts of mixed aggregate or bank-run gravel. As previously stated, bank-run gravel does not occur in the proper proportions of fine and coarse material, but assuming that it did, it can very easily be demonstrated that the 1:2:4 mixture is much richer in cement than the 1:6.

"Take, for example, 2 cubic feet of sand to which we add 1 cubic foot or one sack of cement. When mixed together the cement is practically contained in the voids or open spaces in the sand, so that the resulting mortar is very little over 2 cubic feet in volume. If, now, we add this mortar, which is the 1:2 portion of our 1:2:4 mixture, to 4 cubic feet of screened gravel or stone, the same condition is repeated and the mortar is practically contained in the voids in the stone. As a result the volume of mixed concrete is little more than 4 cubic feet.

"Likewise in adding one sack of cement to 6 cubic feet of bank-run gravel, the cement is contained in the larger amount of open space between the particles, the concrete resulting being 6 cubic feet, the volume of the bank-run gravel. Thus, it should be clear that in one case we have 4 cubic feet of concrete with one sack of cement, and in

Fig. 11.—A slanting screen can be made to separate the sand from the coarse material in bank-run gravel, making possible a great improvement in the quality of the concrete produced.

the other 6 cubic feet of concrete with a like amount of cement, which means that the latter is a leaner and weaker mixture.

"To make a bad condition worse, bank-run gravel invariably contains an excess of sand, which assists further in weakening the concrete. Therefore, it is always better to separate the sand and gravel by screening and afterward remixing the two in the proper proportions.

"For minimum voids and the best concrete, the size of the fine aggregate should grade from $\frac{1}{4}$ inch in the largest dimensions, down to the finest, with the coarser particles predominating, and in no case should fine aggregate be used, of which more than five per cent passes through a sieve having 100 meshes per linear inch."

7. Amount of Water.—The consistency will depend upon the use for which the concrete is intended and upon the process of manufacture necessarily associated therewith.

Three consistencies or mixtures, determined by the amount of water used, are generally called the dry, the quaky, and the wet. The dry mixture is of the consistency of damp earth, and is used where the concrete is tamped into place, being principally useful in steel molds for making products requiring no reinforcement, such as brick, block, and ornamental vases.

The quaky mixture is so named because it is wet enough to quake or shake when tamped. It is used in all molded products requiring reinforcement, such as fence posts, lamp posts, telegraph and telephone poles, drain tile, sewer pipe, ash pit rings and the like; also in engine foundations and the footings of buildings.

The wet mixture contains sufficient water to permit of its flowing from a shovel or wheelbarrow, but not enough to cause a separation of the particles. It is used in building reinforced-concrete structures, such as silos, barns, dwellings and other buildings where the concrete is allowed to remain undisturbed in the forms for several weeks.

CHAPTER III

MIXING

8. Fundamental Principle.—The importance of thoroughly and carefully mixing the ingredients used in the manufacture of concrete is secondary only to the proportioning, because the mixing can not be done until after the proportioning has been accomplished. It is secondary in time but equal in importance.

As stated earlier in this assignment, an essential feature of concrete construction is the coating of every grain of sand with a film of neat cement and the coating of every piece of coarse aggregate with sand-cement mortar. This is the fundamental principle of all concrete construction; an earnest effort to accomplish this result will insure success.

Assuming that proper proportions have been determined, the result so carefully sought can be attained only by thorough and intelligent mixing.

9. Shovel Mixing.—Let us first consider the rather difficult problem of securing satisfactory results where the volume of work does not warrant the installation of a mixing machine.

The first requirement will be a water-tight platform large enough for two men to shovel conveniently from either end as large a batch of concrete as can be used within thirty minutes after water has been added to it. Time is essential, and if on account of meal time, or any emergency, a portion of a batch lies until the cement has become partially hardened, throw it away rather than jeopardize the work.

As proportioning is usually done by volume, one cubic foot is a convenient unit, as it allows full sacks of cement to be used. The required amount of sand should first be spread upon the mixing platform, after which the cement should be spread in a layer on the sand. Two men, using square pointed shovels, will then turn the sand and cement over two or more times until the streaks of brown and gray have merged into a uniform color throughout the mass. The coarse aggregate is then shoveled on and the mixing continued, water being added during the first turning after adding coarse aggregate. Water should be added gently, as from a hose nozzle or the spout of a watering pot, in order to prevent washing out the cement. Turning should continue until the mortar is of uniform consistency throughout, which will usually require at least three turnings after adding water.

Mixing in the above manner will give satisfactory results, but the labor involved is considerable, and on this account it is too common for those attempting it to slight the work and use the concrete in an imperfectly mixed condition.

10. Machine Mixing.—Mixers have been brought to a high state of efficiency and today there are many on the market designed to produce the best results at minimum cost of labor and power. While it is beyond the scope of this assignment to discuss mixers, we may in passing mention one or two of the principles which will assist the concrete manufacturer in making a selection suited to his needs. The batch mixers, whether cubes, cylinders or truncated cones, allow the material to be introduced in any order desired, provided only that each separate batch contains the proper relative proportions of ingredients. After the batch has been placed in the mixer, it is revolved for a specified time, or a definite number of revolutions until either by the shape of the drum itself or by means of deflectors therein, the cement, sand and coarse aggregate have been thoroughly mixed. Most batch mixers are equipped with a small tank from which a pipe leads into the mixer, and when the materials have been sufficiently mixed in a dry state, water is sprayed on them while the revolutions of the mixer continue.

The continuous mixer consists mainly of a number of hoppers for the several materials, placed over one end of a semi-circular trough containing blades or shovels fixed to a rotating shaft. The motive power is generally supplied by a gasoline engine or an electric motor. The dry materials are fed automatically from the hoppers into the trough, mixed and carried along by the blades to the discharge end, water being added; meanwhile the concrete is discharged continuously.

The batch type of mixer is considered by the majority of engineers to give the best results because the measuring of the materials can be positively regulated; whereas with the continuous mixer variations in the amount of moisture in the sand or fluffiness of the cement will cause a variation in the relative proportions of these materials in the mixture. On this account, engineers are inclined to favor the batch mixer.

Lists of manufacturers of both batch and continuous mixers will be found in the columns of current concrete periodicals.

CHAPTER IV

PLACING

11. Final Problem.—But, when all is said and done; when we have selected the best materials, have ascertained the proper proportions of each and the correct amount of water for the consistency required to serve our particular purpose; when by shovel or machine we have combined the different materials required to make concrete, we have produced a mass of material which must forthwith be honestly and intelligently deposited, compacted, and made to take some one of the thousand and one shapes which concrete assumes to serve humanity by increasing the efficiency of man.

This, then is our problem, the placing of the concrete, and we shall find three distinct methods of accomplishing this result.

12. Pressure and Tamping.—Whenever a dry mixture is used in steel molds to produce such unreinforced products as ornamental vases, block or brick, concrete is placed by pressing or tamping. If pressure is applied, it will ordinarily be by means of a press simplifying the process and making it necessary only to see that the molds are adequately and evenly filled in order that the product may be uniform in density. If, however, tamping is the method employed, considerable supervision will be found necessary as the quality of the product may vary considerably unless the tamping is uniformly performed. It is particularly necessary that the mold be tamped while filling, not filled and tamped afterward. The latter method will not only fail to fill the lower corners but will make one-half of the molded product much denser than the other. If tamping is well done by one man (or two if the mold is large) while the mold is being filled by another, there is no reason why the product should not be perfectly satisfactory and as uniform as though made under mechanical or hydraulic pressure. To secure more uniform density and effect a saving of labor, power tampers are used, the multiple tampers being especially serviceable in making block and brick.

13. Agitation.—Neither tamping nor pressure will be of service in the case of those products requiring the introduction of reinforcement, such as tile, pipe, poles and posts. In the manufacture of these and similar products, the steel (in whatever form required for reinforcing) is introduced at the proper place in the mold while it is being filled with a quaky mixture of concrete. The concrete is compacted, forced into corners and around or through the reinforcement, by vigorously stirring the mixture and jarring the mold.

14. Depositing Wet Concrete.—Placing concrete for reinforced-concrete structures, including silos and all sorts of buildings, involves work on a scale warranting the installation of special apparatus to save both time and labor in transporting the concrete from the mixer to the place of use. Elevators, dump cars, and chutes are ordinarily used in the construction of reinforced-concrete buildings. In constructing silos, it is necessary to provide a center hoisting device with derrick and an automatic dumping bucket.

The concrete is poured into forms in which reinforcement has previously been placed. It is then necessary to spade it back from the forms in order to prevent large pieces of aggregate from retaining surface positions when the forms are removed. The larger pieces of aggregate should, as far as possible, be forced away both from the reinforcement and the forms so that they may occupy an intermediate position. Though the subject of "Forms" is treated in another assignment, a word of caution relative to their removal may not be amiss at this time. While no definite rule can be given to fit all local conditions and variations of structure, humidity and temperature, good judgment will suggest that too early removal involves danger, while reasonable delay in removing forms is a wise precaution insuring safety.

Examination Questions

8. What reason is there for using a waterproofing compound in properly proportioned concrete?
9. Wherein does the density test have its value?
10. State proper proportions for fence posts when coarse aggregate is used; when it is not.
11. What is the fundamental principle of making good concrete?
12. What type of mixer do engineers favor?
13. What is the object of spading?

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CHAPTER V

FORMS

The plasticity of concrete and the readiness with which the material can be adapted to all shapes and sizes of construction have, from the beginning of the more extensive use of concrete, made the production of molds of desired form, a very important consideration in all concrete construction work. While iron and steel molds have been used for small members—such as block and brick, and ornamental pieces, in which the same design and size can be indefinitely repeated—larger concrete construction requires individual design determined by local conditions and particular needs. The ease with which concrete may be adapted to such peculiar requirements of individual use is one of the chief merits of the material. Consequently, means must be provided for constructing, at or near the place where the concrete is to be used and from materials easily procured, molds which may be made to fit the circumstances of each individual case. Molds of this diversified character are commonly called forms.

15. **Classification.**—Forms may be roughly classified as follows:

1. Rectangular forms wholly of lumber.
2. Rectangular forms using metal fastening devices.
3. Rectangular metal forms.
4. Circular forms of wood and sheet metal.
5. Circular forms wholly metal.
6. Miscellaneous.

16. **Lumber Forms.**—Contrary to the usual practice in building construction, green lumber will keep its shape in all rectangular forms better than lumber that is thoroughly dry. If dry lumber is used, it should be thoroughly wet before the concrete is placed. The use of oil or grease on the inside of forms is recommended as it prevents absorption of water from the concrete by the forms, and makes their removal easier. Where any fine ornamentation is used, the

molding or other device introduced to vary the surface should be painted with equal parts of boiled linseed oil and kerosene. It is, however, essential that forms should be thoroughly cleaned each time they are used, and that no dry concrete be left sticking to the face of the forms. Forms may be built from stock-length lumber, requiring very little sawing and permitting of the lumber being used later for other purposes. White pine is considered the best lumber for forms, although spruce, fir, and Norway pine are often used. The face of forms should be free from loose knots, slivers or other irregularities, as concrete will reproduce them all with great faithfulness. Matched lumber may be used to afford a smooth finish and very satisfactory results can be obtained by proper care in the construction of forms.

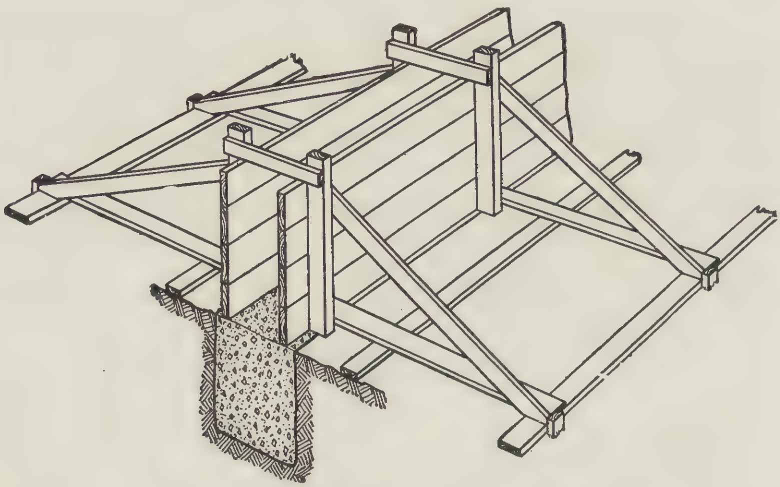

Fig. 12.—Forms for concrete foundation wall.

17. Rectangular Forms.—In the construction of rectangular forms, the first type of construction presenting itself for consideration is foundation work. Where the excavation is made simply for a foundation without cellar or basement, the soil will often be firm enough so that the trench, if carefully excavated, may be used as a form below ground line. In this case the edges must be protected to keep the dirt out of the concrete. In carrying the foundation from the ground line to the level of the first floor, forms must be constructed like those shown in Fig. 12. These forms may either be constructed in sections and then set in position, or they may be built in place. It should be noted that the forms in Fig. 12 are suspended over the trench and are not allowed to rest upon the new concrete.

If the inner and outer parts of the form are built separately, they must, when put into position, be levelled and plumbed carefully. Whether built in sections or built in place, forms must be braced thoroughly and tied together, as the essential duty of any form is to keep rigid until the concrete has hardened.

Fig. 12 also shows a convenient method of suspending the bolts which are to be embedded in the concrete for securing the wooden sill or wall plate to the foundation. These bolts are also shown in Fig. 13. They should not pass

Fig. 13.—Foundation wall for a small shed, showing bolts for attaching the wooden sill to the concrete foundation.

through the cleats but should be carried by a block or small board tacked to the cleats; otherwise it would be difficult to remove the form without destroying the cleats.

Before filling the wooden forms, the surface of concrete previously placed in the trench should be swept off, to remove dirt, leaves or other foreign matter. If it has become dirty, it should be washed and while still wet brushed with a cement and water grout mixed to the consistency of thick cream. Concreting should be resumed before the grout has had time to dry. This treatment will insure a good bond between the old concrete and the new, and should always be used when joining work that has hardened.

Forms for foundation piers and for the foundation of all kinds of machinery are constructed in substantially the same manner as for regular building foundations. The construction of machinery foundations is essentially a problem of securing the necessary mass and weight, consequently the greater part of the foundation will be under ground and all that is required above ground is an open box of sufficient strength to maintain the concrete in the desired form while hardening (Fig. 14).

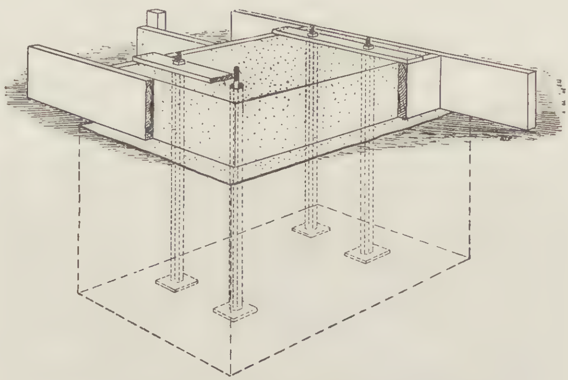

Fig. 14.—Sketch showing gasoline engine foundation.

Where the excavation for a cellar is made by team and scraper, the sides will not be perpendicular and the excavation will usually be somewhat larger than the dimensions of the cellar wall. Consequently, it is necessary to use both inner and outer forms. Each form consists of uprights spaced close enough to prevent any spreading or bulging of the sheeting when subjected to the outward pressure of the fresh concrete. The inner form should be securely braced in a perpendicular position by lumber braces from the floor of the excavation. The outer form should be fastened to the inner form by wires running through both near the bottom, and at the same place the forms should be separated by spacing blocks of the width determined upon for the cellar wall. The outer form should, like the inner, be perpendicular unless a slight batter is desired, in which case the spacing blocks should be lengthened to spread the bottom of the forms apart and increase the thickness of the wall at the bottom without interfering with the established thickness of the wall at the top. The wires connecting the two forms should be drawn tight by twisting with a large nail or rod until the forms are drawn firmly against the spacing blocks. The top of the uprights should be joined by cleats. The method just described produces a very rigid form. Fig. 15 shows another method of form construction for low walls.

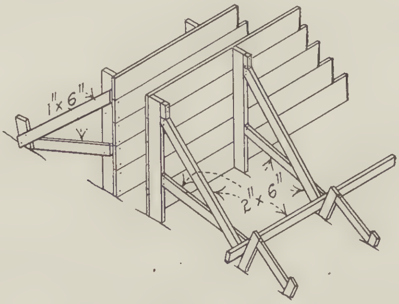

Fig. 15.—Externally braced forms.

If an outside entrance to a cellar or basement is desired, the forms should be constructed at the same time that the forms are built for the cellar walls. When in position, these forms will rest upon the floor of the excavation made for the

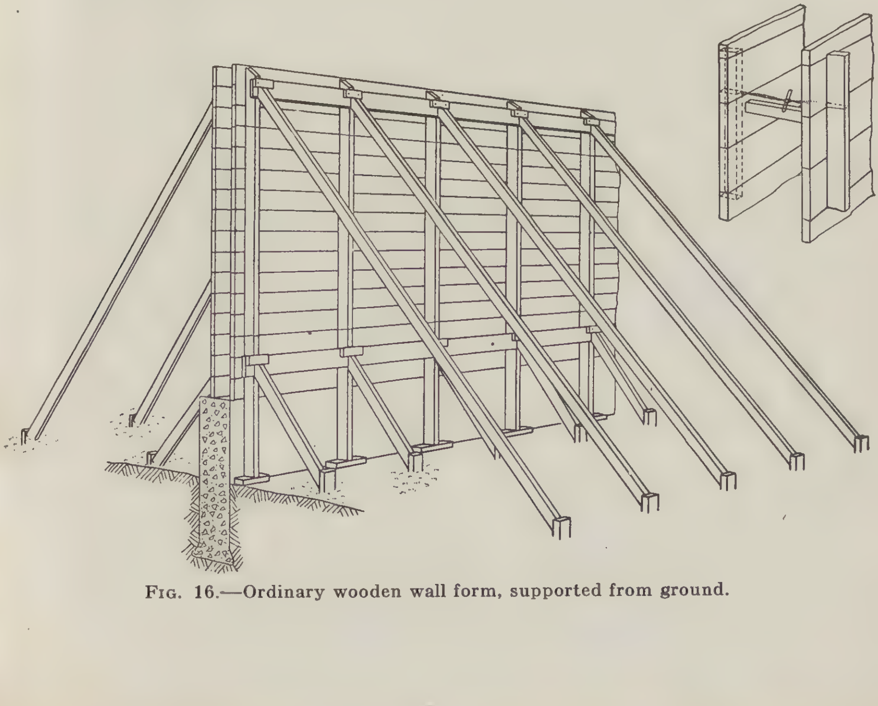

Fig. 16.—Ordinary wooden wall form, supported from ground.

steps. If the excavation for the entrance is carefully made, only the inside form will be required until ground line is reached. As the walls will project above the ground where they join the building, and slope from that point to the opposite end of the entrance, an outside form will be required above the ground line. By properly bracing the form, one side wall may be made and, after it has hardened, the form reversed and used for the other side. After both side walls have been made, forms for the steps giving desired height of riser and width of tread may then be securely braced between the side walls.

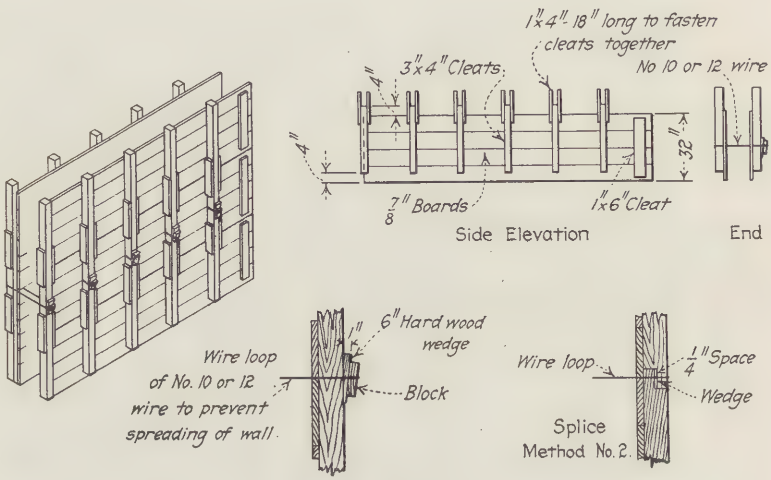

FIG. 17.—Movable wall forms.

Concrete walls above the cellar may be built either as a single wall or as two walls with an air space between them. Fig. 16 shows the necessary form construction for a single wall. The forms may be built in sections or in place. Sectional or unit forms can be used a number of times if carefully removed and assembled, making a large saving in the amount of lumber used. The wire ties shown in Fig. 16 are used to secure the forms against pulling apart, being wound around opposite studs and then twisted with a stick, as a turnbuckle, until the studs are held tight against the spacing blocks. These spacing blocks must be removed as the concreting progresses. Fig. 17 illustrates a method employed by one construction company for building a wall of considerable height by means of movable forms.

In the construction of double walls, such as in ice houses, the intervening air space is not usually wide enough to accommodate two sets of forms. Therefore the hollow wall is usually constructed by placing in the forms cores which are later withdrawn.

Forms for retaining walls and bridge abutments are erected in a similar manner to building walls, although usually made of much heavier timber. Figs. 18 to 22 inclusive show the form construction employed in the construction of the abutments for a railroad bridge a few miles west of Fort Dodge, Iowa, on the Illinois Central Railroad. These views also show the method of handling the concrete materials and the transporting and placing of the concrete. The industrial car and track, and the chutes should be noted.

Forms for walks (Fig. 23) and floors should consist of 2-inch lumber in width equal to the desired thickness of the walk or floor, staked in the earth to form slabs of the desired size. The concrete is mixed wetter than for two course work, and where the walk or floor is laid in one course, slabs should be laid alternately, allowing cross forms to remain in place until ready to fill intermediate slabs. This method is also used extensively in two-course work, although many prefer to work consecutively, moving the cross piece each time a slab is completed. If laid continuously, care must be exercised to preserve the vertical joints through the entire walk. Horse blocks or carriage steps may be constructed where the walk joins the driveway by the use of simple box forms.

The modern farmer is making use of concrete for the construction of various types of tanks, such as the stock watering tank, the hog feeding trough, the dipping vat, and the hog wallow, all of which may be constructed by the use of rectangular lumber forms.

The general method of constructing rectangular tanks above ground consists in erecting an outer form, usually of 2-inch lumber, in which the concrete floor of the tank is placed, and the surface finished as desired, after which the bottomless inner form, which must be previously prepared and ready for immediate use before the previously placed

Fig. 18.—Form construction for railroad bridge abutments. Reinforcing rods in place.

Fig. 19.—View showing method of handling the concrete materials in constructing railroad bridge abutments.

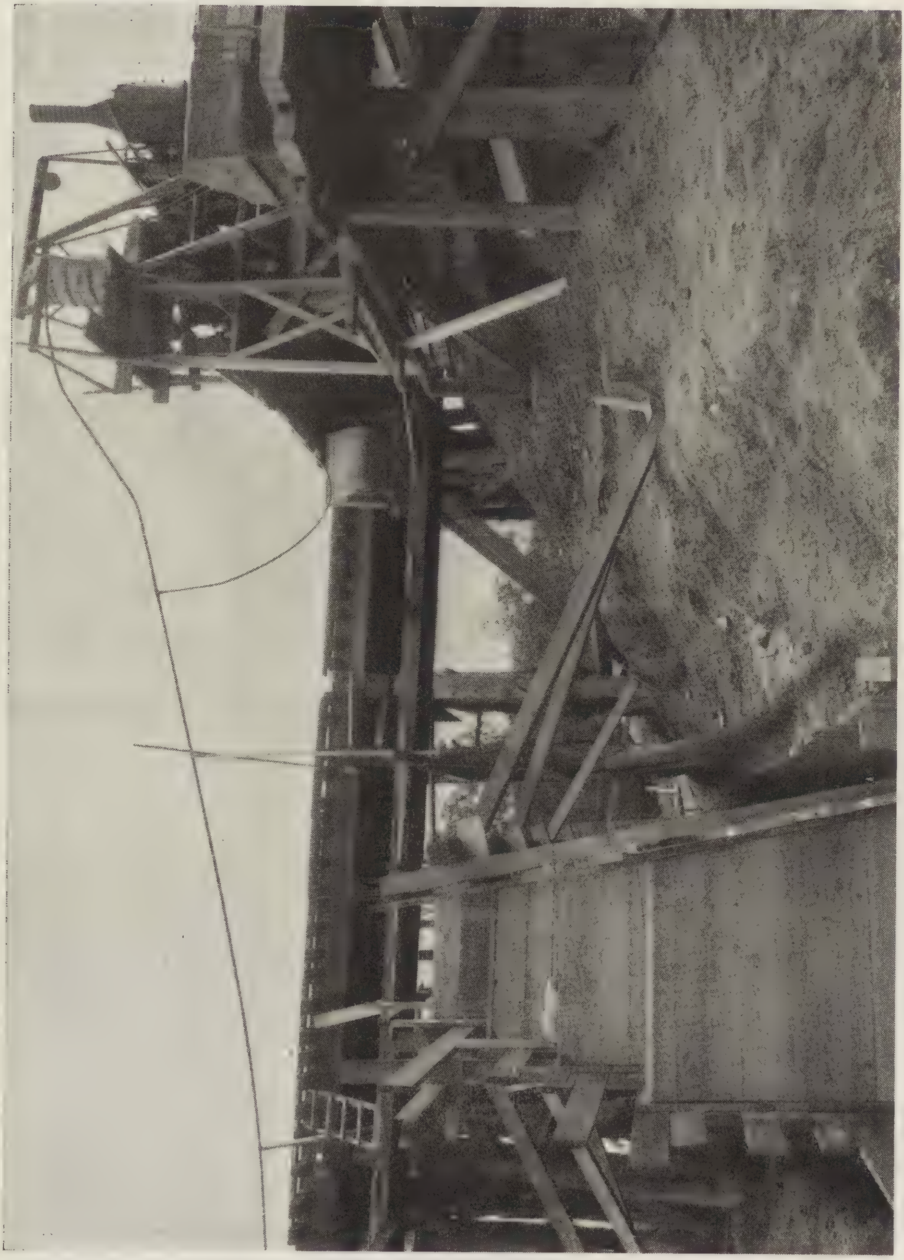

Fig. 20.—View showing method of transporting and placing concrete for railroad bridge abutments.

Fig. 21.—General view of forms and plant for constructing railroad bridge abutments.

Fig. 22.—Concrete in place in abutments of railroad bridge.

concrete has hardened, is quickly inserted and securely fastened in place by cleats joining the uprights of the outer and inner forms (Fig. 24). The method of constructing rectangular tanks underground differs only in that the earth usually forms the outer form, and a wood form is required

Fig. 23.—A concrete sidewalk on the farm,

for the roof. In constructing septic tanks, provision must be made for the several partitions and compartments necessary to secure decomposition of the sewage and disposal of the effluent.

Two methods are used with equal satisfaction in manufacturing small troughs which need not necessarily be built in place. One is to use a box mold and finish the interior with a straight batter or a concave surface by striking it out with a template. The other method is to use a core of firm clay or wood made in shape to correspond with the inside of the trough. A bottomless box is placed over the inverted core and by filling the box with concrete and striking it off level, the trough is manufactured upside down (Fig. 25).

The simplest deviation from home-made molds is to purchase clamps for holding forms in place, thus doing away with nailing them to the uprights. There are several systems of clamps on the market, some of which are very

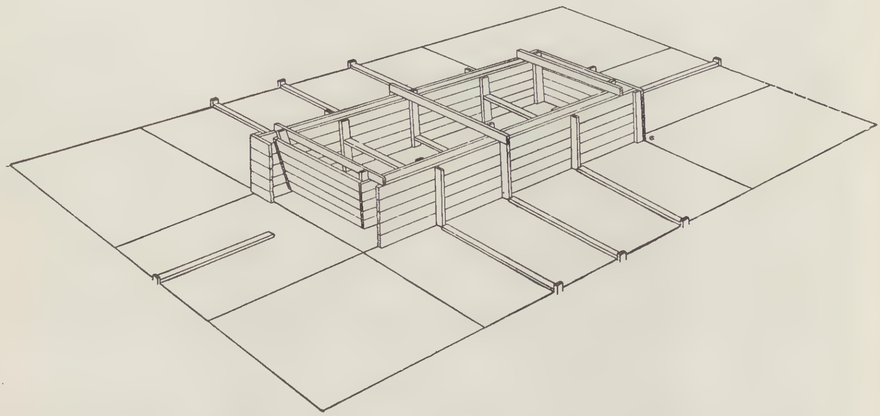

Fig. 24.—The easiest form to construct for building concrete tanks is of the rectangular shape. The inner form is supported on the outer after the concrete tank floor is in position.

ingenious, and all of which are designed with two purposes in view, the first being to facilitate the erection and removal of forms, and the second being to save loss of lumber from repeated nailing and tearing down.

A still wider departure from the home-made forms brings us to those constructed wholly of metal, which provide a rapid and economical method of concrete construction where a large amount of work is to be done along uniform lines. Only continued repetition, however, will justify the purchase of metal forms. Where the opportunity occurs to rent metal forms for any work of considerable importance, a saving may be effected and the quality of the work somewhat improved on account of greater surface uniformity secured by use of the metal forms.

18. Circular Forms.—Circular forms are extensively used in the construction of tanks because a round tank is more economical to build and will resist frost action better than a tank of any other shape. The construction of a circular form presents greater difficulty than does that of a rectangular form, and it is usually better for several of those who desire to construct tanks to determine upon a standard size and join in the use of a set of forms, or if this can not be done, a set of forms may be rented if but a single tank is to be made. For a 10-foot circular tank, 2 feet 6

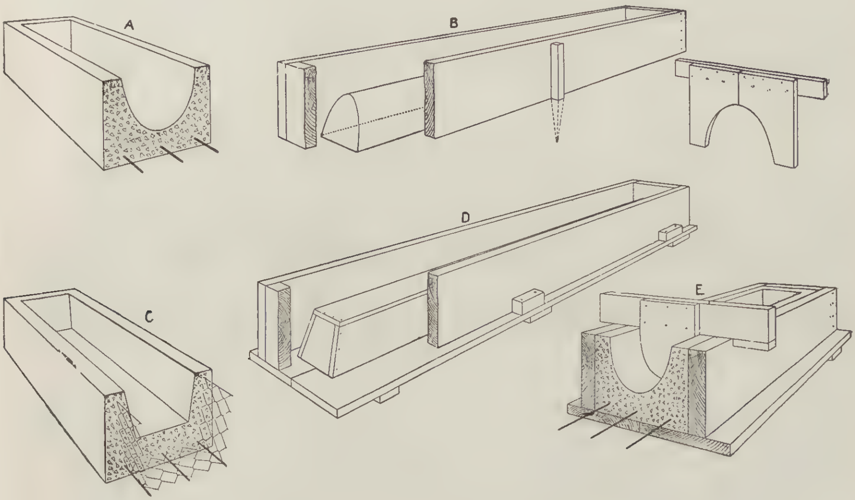

FIG. 25.—Small reinforced-concrete troughs may be made by the use of a wooden or clay inside form in an inverted position, or the shape of the interior may be formed by the use of a wooden template with the side form as a guide.

inches in depth, the forms usually cost about $50, while the cost of the tank itself, exclusive of sand and gravel, is only $30. Forms for circular tanks (Fig. 26) consist of an inner and outer wooden frame covered with sheet iron. (Silo forms may be used for the outer forms of large tanks). The height of the inner form is equal to the inside depth of the tank and the height of the outer form is equal to the sum of the inside depth and the floor thickness of the tank. After the inner and outer circles of the form have been laid out, segments are cut from 1-inch lumber and a wooden frame is built up, fence fashion. No. 22 gage galvanized iron is then attached by screws or nails. The inner form should form an angle with the outer one to give proper batter to the inside of the tank to prevent bursting in case of freezing.

The selection of silo forms presents to the modern farmer one of the most important problems in connection with the use of concrete. What are known as homemade silo forms are usually constructed in 3-foot sections, but it is hardly desirable to construct a set of forms for the express purpose of building one silo. It is far better for farmers to unite in the matter, as a set of forms may be used for constructing a large number of silos. However, if one must build his

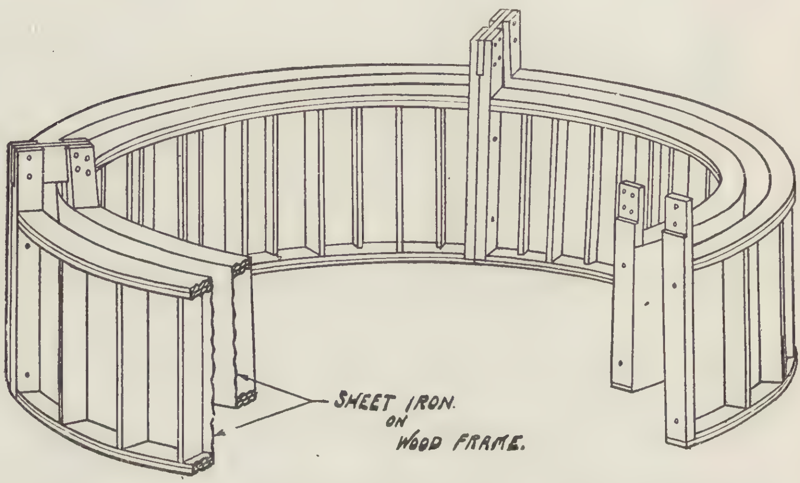

FIG. 26.—A circular form can be made of sheet steel supported on a wooden frame work. The inner form is suspended from the outer as shown.

own forms, a most ingenious model is that of Mr. David Imrie, Roberts, Wisconsin, who has introduced his form to hundreds of farmers in connection with the work of the Wisconsin Farmers' Institutes. The inner form consists essentially of hooped sheet metal securely clamped and braced. No. 28 gage galvanized sheet iron is used and the form is assembled in eight segments which are bolted together. The outer form is made of 18 or 20 gage galvanized sheet metal 3 feet in width, in two or more pieces joined by heavy band iron riveted to the ends of each piece, which is turned at right angles and drilled to receive the bolts drawing adjoining sections together. Forms of this type have been built at a cost varying from $25 to $50.

Practically all silos now built are roofed. The construction of the roof form is a simple matter, requiring only a box for the cornice and 2-inch by 4-inch rafters radiating from the apex to the roof edge, on which 1-inch by 6-inch sheeting is laid to receive the concrete.

Many commercial systems of silo construction are now upon the market. Fortunately, most of them are meritorious and will result in more satisfactory work than can be obtained from homemade molds unless one is thoroughly familiar with the qualities and method of handling cement and concrete. The various commercial silo systems are operated under different methods. The forms are constructed wholly of metal and some companies sell them outright to an association of farmers who desire to construct silos; some companies rent their forms for the construction of a single silo; some companies construct a silo for the farmer, acting in the capacity of contractors and guaranteeing their work in every way.

19. Miscellaneous Forms.—The miscellaneous uses of concrete about the barn, barnyard, and farm in general are innumerable. The preparation of forms for the many uses to which concrete may be put affords pleasant exercise for the ingenuity of any one familiar with the uses of concrete. A few of the possibilities of smaller construction are merely suggested: concrete stalls, mangers, hens' nests, hotbeds, pits for wagon scales, curbing for old wells, pump pits, and waste water receptacles. The form for the last mentioned consists of earth excavation for the outer form and an empty half barrel for the inner form, which indicates how simple concrete construction may be made.

The removal of the form is a matter requiring very careful consideration. A great deal of work has been injured and not a little has failed, because of undue haste in removing forms. Two or three days' additional time allowed to new concrete before removing the forms often marks the difference between defective and thoroughly satisfactory work.

Examination Questions

14. Should green or dry lumber be used for building rectangular forms?
15. What are the essential requirements for constructing machinery foundations?
16. What should be the width of lumber used in building forms for walks and floors.
17. Under what conditions are metal forms economical?
18. Of how many segments does the inner silo-form of the Imrie model consist?
19. How may a simple form be constructed for waste-water receptacle?

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CHAPTER VI

FOUNDATIONS

Concrete is especially adapted for use in building foundations because of the following characteristic qualities:

1. Compressive strength.
2. Durability.
3. Moderate cost.
4. Ease of Construction.
5. Adaptability to irregular excavations.
6. Capacity for reinforcement.

Plain, or unreinforced, concrete shows its greatest strength under direct compression. Carrying capacity is the quality chiefly sought in the selection of material for the foundation of any building. Moreover, concrete lasts forever without repairs, and permanence is a consideration scarcely secondary to strength in determining a choice of foundation material. The cost of a well-built concrete foundation is considerably less than that of one constructed of any other building material of equal strength and durability. Under average conditions, the time required for building a concrete foundation is shorter than that required for one of brick or stone. Concrete is the only foundation material which readily adapts itself to slopes, change of grade, or other irregularities in the subgrade on which the foundation is laid. Wherever conditions require a foundation of restricted area, or where a side hill exposes a portion of the foundation wall to danger of accidental injury, or where vibration of engines and other machinery must be withstood—in any of these cases, concrete has demonstrated its adaptability by permitting the introduction of sufficient reinforcement to satisfactorily perform the duty demanded.

Consequently, concrete is supplanting all other materials for building foundations of every character, irrespective of the character of the superstructure. Some of the principles which must be observed to secure the best results will be here outlined.

20. Materials.—The proportioning, mixing, and placing of concrete has been thoroughly discussed in Assignment 2, and the practices therein recommended should be rigidly observed. Further, it is often possible in foundation work to increase the size of the largest aggregate up to 2 inches or even 2½ inches. Wherever large sizes of hard, durable gravel or broken stone can be used, additional strength is secured; for this purpose field stones may be employed advantageously.

21. Excavation.—In preparing for the erection of any rectangular structure, a base line should first be determined upon and from the base line the several corners should be ascertained by accurate measurement at right angles or at such other angles as may be desired in structures of irregular shape. The corners should be staked and definitely fixed by a tack driven in the top of each stake. All measurements and angles should then be checked back to the base line. Several feet outside of the line of stakes other stakes should be set to over-reach the corners, or a frame may be built 10 inches above ground, from which lines are then run to pass exactly over the tacks set in the stakes. These lines show the outside of the proposed excavation, and by measuring the width of the foundation and running parallel lines that far inside of the first lines, the lay-out is ready for excavation.

The depth of excavation depends upon the height and character of the building to be erected, but should always go to solid earth, and should at least be lower than frost line. If the ground is filled with surface water at certain seasons of the year, drainage should be provided from the bottom of the foundation trench to a natural outlet.

22. Footings.—As a convenience in setting forms, footings are sometimes provided where ground is firm. Wherever a foundation is to be constructed on filled ground which can not, by rolling and tamping, be made solid enough to guarantee the permanent carrying of the superimposed load without settlement, the weight must be distributed by a layer of concrete wider than the foundation itself. This is known as a footing. It may be twice as wide as the foundation but must be thick enough to prevent cracking, and may have either sloping or stepped sides. In extreme cases of very soft earth requiring excessively wide footings, crossbars or reinforcing rods are introduced in the footings to distribute the foundation load without injury to the concrete slab.

Kidder (Architects' and Builders' Pocket-Book) gives bearing power of soils as follows:

Description	Bearing Power in Tons per square foot	
	Minimum	Maximum
Rock—the hardest—in thick layers in native bed	200	....
Rock equal to best ashlar masonry	25	30
Rock equal to best brick masonry	15	20
Rock equal to poor brick masonry	5	10
Clay on thick beds, always dry	4	6
Clay on thick beds, moderately dry	2	4
Clay, soft	1	2
Gravel and coarse sand, well cemented	8	10
Sand, compact and well cemented	4	6
Sand, clean, dry	2	4
Quicksand, alluvial soils, etc	0.5	1

Concrete for footings should be mixed in the proportions of 1 sack of Portland cement, 3 cubic feet of clean, coarse sand, and 5 cubic feet of gravel or broken stone varying in size from $\frac{1}{4}$ inch up to 2 inches; if reinforced, the proportions should be 1:2:4. Enough water should be used to form a quaky mixture but not enough to cause the cement and aggregate to separate in placing. Concrete foundations and footings may be keyed by partially embedding in the footing vertical rods or horizontal I-beams; in light structures a similar effect may be produced by casting on the footing a central longitudinal projection which will form a tongued-and-grooved joint with the foundation. If the placing of the foundation is delayed until the footing has hardened, the latter should be cleaned, roughened, and wetted, and then grouted with a mixture in the proportion of 1 sack of Portland cement to 1 cubic foot of sand, mixed to the consistency of thick cream.

23. Simple Foundations.—Where there is to be no cellar or basement under a building, and the nature of the ground is such that the excavation can be made for the exact width of the foundation, forms below ground line are unnecessary provided the earth is firm enough to prevent "caving in" of the sides. It is, however, necessary to protect the edges and sides (especially on the side opposite that from which the concrete is poured) by burlap aprons made by tacking a piece of burlap on a piece of lumber 2 by 4 inches, long enough to rest on cross pieces bridging the excavation. When the ground line is almost reached, forms previously constructed of 1-inch boards on 2-inch by 4-inch studding must be placed to receive the concrete from ground line to the top of the foundation wall. (See Fig. 12, Assignment 3). No appreciable time should elapse between placing the concrete below and above ground, as an interval of more than 30 minutes will produce a line of cleavage, seriously weakening the wall and lessening its watertightness.

24. Piers and Engine Foundations.—Foundation piers for additional supports under large or heavily-loaded buildings are constructed in the same manner as simple foundations, the size being determined by the estimated load and the character of the ground. The footing is important, as the sole object of such a pier is the distribution of the load.

Foundations for gasoline or steam engines and for any machinery subject to considerable vibration are constructed in the same manner as foundation piers. (See Fig. 14, Assignment 3). The size and depth is determined by the amount of vibration to be withstood. The problem is simply to build in the earth, a solid block of concrete of weight sufficient to withstand the action of the engine bolted to its top. Casings for the bolts are made of 2-inch pipe, resting on plates at the lower end of the bolts; they are imbedded in the concrete and provide for any necessary adjustment of the bolts when setting the engine in place. The length of each casing equals the length of the bolt to be imbedded; by tightening the nut on each bolt above the template, the casing fits snugly against the template, and the top of the bolt is brought to proper height. The templates can be made from 1-inch material, and will be sufficient for placing the casings in smaller engine foundations; for larger foundations cross bracing should be added. In setting bolts, first nail the templates securely in place, then mark accurately the position of the bolts and bore holes only slightly larger than the bolts. Be sure the bolt holes are correctly located. Bolts and casings are now set in place, centering casings with bolts by several nails or by wooden strips lightly nailed on the under side of the templates. Proportions of 1:3:5 may be used in foundations for gasoline engines and cream separators. A mixture of 1:2:4, using aggregate up to 2 inches or $2\frac{1}{2}$ inches is recommended for steam engines and large machinery.

CHAPTER VII

WALLS

25. Cellar and Basement Walls.—Wherever the excavation is made for a cellar under a building, the problem includes not only the construction of a wall to serve the purpose of a foundation for the superstructure but of one which will also insure a cellar warm in winter, cool in summer and dry at all seasons. Concrete walls of suitable thickness solve the problem of heat transmission and if properly built, the cellar will be always dry. Proper drainage however, should be provided. While a concrete cellar wall may be constructed so impermeable that water standing outside will not penetrate to the interior, drainage to natural outlets is a wise precaution and should not be omitted except in soil that is dry throughout the year.

When the cellar excavation (often made by team and scraper) has irregular sides and is somewhat larger than the actual dimensions of the wall, it will be necessary to use both outside and inside wall forms. Only in small excavations shoveled by hand and left with true sides in firm earth free from indications of caving, can the earth be used for the outer form.

In using forms for both the outside and the inside of the wall, quite a large amount of lumber would be required, if forms for the entire work were constructed at one time. To obviate this, forms can be built in sections, each section being of the full height of the cellar wall, and as long as convenient to build and set in place. An entire section should be filled at one operation in order to avoid horizontal joints or lines of cleavage in the concrete.

At the end of the section, a piece of 2-inch by 4-inch lumber, with both edges bevelled to permit of easy removal, is fastened to the face of the partition board used as a stop-off at the section's end (Fig. 27). This makes a tongue-and-groove vertical joint. When the forms are ready to fill for the adjoining section, the end of the partially-hardened section must be cleaned, wetted, and coated with neat cement grout mixed to the consistency of thick cream. Attention is called to the preference in building practice for vertical joints in foundation and cellar walls, whereas horizontal joints are preferable in the upper part of the building.

Sectional forms are better and more economically constructed by building them flat upon the ground than by constructing them in the position in which they are to be used. Care should be exercised to build them true and to have the face as free from irregularities as possible. The sheeting for the inside of the wall should be surfaced on the side next to the concrete to give a smooth interior finish.

The outer and inner form should be joined at the top by nailing cleats between the uprights, being careful to separate

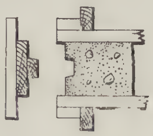

Fig. 27.—Method of joining foundation walls where it is necessary to leave an expansion joint, or where concreting has been discontinued for any reason.

the forms the exact width of the wall. The forms should be united a short distance from the bottom by double wires and should be separated at the same place by wood spacing blocks of a length equal to the thickness of the wall. When the spacing blocks are placed, the double wires are twisted by the use of a large nail, so that the outer and inner forms are firmly fastened together. They are supported by securely bracing the inner form, so that the wall will be plumb.

If desired to provide the foundation with greater resistance to lateral pressure, or to afford a firmer base, "batter" in the wall may be secured by lengthening the spacing block which separates the outer and inner forms.

Anchor bolts are imbedded in the concrete at suitable intervals for fastening the wall plate to the foundation (Fig. 28).

26. Cellar Floors.—The methods of building concrete walks are fully described in another assignment. The methods of building cellar floors are similar. To avoid repetition, only the points of dissimilarity will be stated here.

Where the ground is firm and well drained, the sub-base may be omitted and the concrete floor laid directly on the ground.

Drainage should be provided, preferably toward the center of the floor. The top of the floor should be given grade enough that water accumulating from scrubbing or other causes will run off through a tile drain laid beneath the floor and communicating with a natural outlet.

Where a basement floor is below the level of ground water, the floor should be laid in a single sheet instead of being

Fig. 28.—Concrete basement wall under residence showing method of anchoring wall plates to wall.

divided into slabs. The concrete should be mixed in the proportions of 1:2:3 and the floor reinforced in both directions with $\frac{1}{4}$-inch rods 8 inches apart, or by wire mesh having an equal cross sectional area of metal.

27. Entrances.—Outside entrances to cellars should be constructed by building (at right angles to the cellar wall) forms for side walls sloping from the top of the foundation down to the ground and from the cellar floor up to the top of the proposed stairway. If excavation is carefully done, the earth may usually be used for the outer form. By pouring one sidewall at a time, and reversing the form by changing uprights to the other side of the sheeting, one form may be used for both sides of the entrance. The form for the steps may be built after the side walls are hard enough to remove the forms. After the desired measurements of tread and riser have been decided upon, the plan should be laid out on the side walls, cross pieces wedged between them and secured by bracing. The concrete used in the construction of the base should be as wet as possible without flowing from one step to another.

The $\frac{3}{4}$-inch wearing course of the risers may be placed either by using a thin metal partition or by plastering the mortar on the inside of the face form before placing the coarse, wet concrete. The wearing course of treads is placed as in sidewalk work and should be finished by wooden float to a surface reasonably smooth but rough enough to afford a good foothold.

28. Window Frames.—Closer joints will be secured under cellar windows if the frames are not placed until the concrete is ready to receive them. However, the frame must be ready and quickly placed in order to avoid one of those delays which will allow concrete to set and make it necessary to clean, roughen, wet, and grout it before a fresh layer can be added without producing a horizontal line of cleavage. The position of the frame should be maintained by nailing wood strips to it or driving nails through and leaving them projecting into the concrete.

29. Finish.—Concrete for cellar walls should be of such consistency that when poured into the forms, it will settle to place by gravity. While the forms are being filled, the coarser aggregate should be spaded away from the face of the wall, bringing the mortar next to the forms. The mixture recommended for foundations and basement walls, 1:3:5, provides an excess of mortar for this purpose. Spading is equally important on the interior and the exterior. On the interior it gives a more finished surface and on the exterior it increases watertightness. On the outside of the wall above ground line, the plastic appearance which walls will have after forms are removed may be overcome by removing the surface film of mortar by brushing with a wire or a stiff fiber brush and washing the wall with the acid solution mentioned in Assignment 5 on "The Surface Finish of Concrete."

30. Removal of Forms.—Not only the proportions of ingredients and consistency of concrete itself, but the weather conditions have marked influence upon the time of hardening. Consequently no definite rule can be given for removal of forms. Two to three weeks will suffice under average conditions. Where the earth is utilized for the outer form more time will be required than where both forms are of lumber. Too early removal spells failure, and judgment must be exercised.

31. Block Foundation Walls.—Well-made concrete blocks are extensively used for foundation and cellar walls. For the latter purpose, they possess the advantage of an interior air space which helps to preserve an even temperature in the cellar. Care should be exercised that the blocks are well made of properly-selected and proportioned materials, mixed wet enough so that the percentage of porosity and absorption will be low. For both foundation and cellar walls, blocks must invariably be laid in cement mortar mixed in the proportion of 1 sack of Portland cement to 2 cubic feet of sand, and the joints must be thoroughly filled. For this purpose a template or mortar gage may be obtained from the manufacturers of leading block machines.

32. Walls for Superstructures.—The recent statement that the annual fire loss of American farm buildings equals one-fourth of their total cost should be sufficient argument for concrete—a material that will not burn.

There are several methods of using concrete for the main portion of all classes of buildings. The most common forms of its application are concrete block and monolithic walls. The concrete block is fully discussed in another assignment. Monolithic walls may be either plain or reinforced. The principal reason for reinforcing monolithic concrete walls is to prevent cracks from the expansion and contraction of the concrete, caused by changes in temperature. All walls exceeding 12 feet in height should be protected by sufficient horizontal and vertical reinforcement which should be computed according to the dimensions and design of the particular structure. It is seldom necessary to reinforce monolithic walls over 8 inches in thickness, when less than 12 feet in height, except around window and door openings. One-fourth inch rods should be placed from 1 inch to 2 inches back from the surface of the wall, and 2 inches from the angles of openings; three rods above and two on each side of the openings; two rods below windows—all projecting 10 inches beyond the point of intersection. Diagonal rods $2\frac{1}{2}$ feet long should be placed to pass intersections of horizontal and vertical rods.

The monolithic concrete wall lends itself more readily than any other type of building construction to the individual taste of the builder as to variety of design. In this respect it has no limitation except that of the builder's ingenuity in the construction of forms. Forms for walls above ground must necessarily be more carefully constructed than those for cellar work, as more perfect alignment is required and better surface finish desired. In building walls above ground level, continuous forms (Fig. 17, Assignment 3) are sometimes used to avoid vertical joints.

Several systems of clamps are now manufactured for constructing forms of 2-inch plank. They generally provide for courses 24 inches in height, the same form being moved upward as soon as the last course has hardened sufficiently, thus effecting a great saving in lumber although requiring a little more time in building.

Metal forms are now obtainable and are in use by numerous contractors. They are serviceable and satisfactory, but too expensive for the individual builder unless he contemplates constructing a large number of buildings.

Examination Questions

20. How does the cost of a well-built concrete foundation compare with that of one constructed of any other building material of equal strength and durability?
21. What is a footing?
22. What would be the effect upon a foundation wall if an interval of more than thirty minutes between placing concrete below and above ground were allowed to elapse?
23. When the cellar excavation has irregular sides and is larger than the dimensions of the wall, what forms should be used?
24. When may the subbase be eliminated in building a cellar floor?
25. What is the principal reason for reinforcing monolithic concrete walls?

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CHAPTER VIII

THE SURFACE FINISH OF CONCRETE

Concrete is a product resulting from scientifically combining certain ingredients to form a material useful in construction because of its own distinctive merits and not because of its resemblance to any other natural or artificial product. When properly treated it develops beauty; it is not the beauty of onyx, marble, or granite, but the beauty of concrete. If taken for what it is, rather than what it resembles, its qualities, uses and advantages are found worthy of exhaustive research.

33. Mortar Facing. Whenever it is desired to secure a rich mortar surface, one of three methods is employed. A mortar mixed to the consistency of paste may be spread on the inside of the forms and the concrete filled in behind it and all tamped at one operation, to secure a good bond. A board or block of the desired thickness may be inserted,

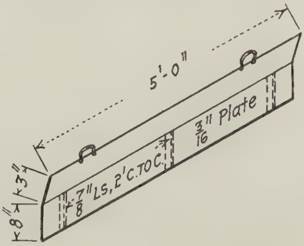

Fig. 29.—Type of metal facing form.

the concrete filled in and the board removed leaving a space to be filled by the mortar, using in this case a slightly wetter mixture. The third method, and by far the most general practice, consists in using a partition of sheet iron or steel having angle iron attached to one side to gage the thickness of facing mortar (Fig. 29). Handles are attached to the top so that, as the concrete is placed behind and the face mortar in front, the partition is gradually moved upward. The use of a rich mortar is not so prevalent as it was in the earlier stage of the concrete industry because, as will be explained, far more pleasing effects may now be secured by other methods.

34. Spading.—Where a smooth concrete surface is desired, a spade or face cutter is used, which is forced down beside the forms while the concrete is being placed, forcing the coarse aggregate back and allowing the mortar to fill the spaces next to the forms, resulting in a surface as smooth as the face of the forms.

35. Washed Surfaces.—Probably the cheapest method of finishing a smooth concrete surface consists in removing the forms at the end of a period varying from six hours to three days, according to the weather conditions, and finishing the surface by the use of a plasterer's float or small board, using sand and plenty of water between the board and the wall to do the cutting. If this work is done at a time when the concrete is neither too green nor too hard, good results can be secured cheaply, as a laborer will in this manner cover one hundred square feet in an hour. This method of finishing is recommended for factory construction and the rear of apartment buildings and in general for such walls as do not require especial treatment.

36. Experimentation.—Careful trials should be made before undertaking any artistic treatment upon actual construction work. The possibilities and variations in this work are unlimited and some methods of work are expensive. Consequently any one intending to attempt the construction of an artistic surface should first try out the proposed method on several small samples from 6 to 12 inches square.

The surface desired will determine the selection, gradation and proportioning of the aggregate, and will also influence the consistency of the mixture. Some of the more common materials selected for aggregate will be limestone, granite, marble chips, and other stone, gravels, and sands of various colors.

Whenever it is necessary to use expensive materials to obtain the surface finish desired, they are used only in the mixture applied as a facing for surfaces to be exposed. As a rule, the facing mixture varies from one to one and one-half inches in thickness, the remainder of the work being of ordinary concrete. However, both must be placed in the forms at the same time to insure a perfect bond and a solid mass. The third method already described for placing mortar on the face of concrete work is recommended in this connection; that is, the use of a partition of sheet iron or steel. As rich mortars always have a tendency to develop minute cracks, they should be avoided so far as possible, and a mixture of one sack of Portland cement to two and one-half cubic feet of aggregate is therefore recommended in the production of artistic concrete surfaces. The thickness of the facing material should not be less than one inch when fine aggregate is used and whenever coarse aggregate is used it should be at least twice as thick as the greatest diameter of the largest aggregate used.

37. Brushed Surfaces.—The plaster-like appearance of the concrete as it comes from the forms has always been objectionable, and one of the best methods of overcoming this is to remove the forms in about twelve hours (it being always understood that the time of removal is dependent upon the weather and the nature of the construction). As soon as the forms have been removed, if a brushed surface is desired (Fig. 30), the concrete should be brushed while still green with a steel brush or one of stiff palmetto or other fiber bristles. A good brush may also be made by clamping together enough sheets of wire cloth to make a brush about 4 inches wide. If the concrete hardens so that the mortar can not be brushed away from the coarse aggregate, the mortar may be softened by a solution of muriatic acid. After brushing, the work should be treated to an acid solution, and for this purpose, if standard Portland cement has been used, the solution should be one part of commercial muriatic acid to three parts of water. After the use of an acid solution the work should be washed immediately and thoroughly with clean water, as any acid remaining upon the face of the work will ultimately cause streaks and discoloration.

The following materials are recommended as suitable aggregates for the production of desirable brushed surfaces, it being understood in using any of them for aggregates that the mixture is to be one sack of Portland cement to two and one-half cubic feet of aggregate.

Yellow marble screenings up to $\frac{1}{4}$ inch; red granite screenings up to $\frac{1}{4}$ inch; black marble graded from $\frac{1}{8}$ inch to $\frac{1}{2}$ inch; white marble graded from $\frac{1}{8}$ inch to $\frac{1}{2}$ inch; river or

FIG. 30.—Brushed concrete surface. No special facing.

lake gravel graded from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch. To secure economy, limestone may be substituted for white marble and either black granite or trap rock may be substituted for black marble.

The above materials are merely suggestive of the possibilities of concrete surfaces. Infinite variations may be made by substituting and combining materials. If one takes trap rock, red granite, and limestone, for instance, by merely increasing or diminishing the size of one or two of the ingredients, a great many combinations may be effected, all of which will produce desirable surfaces for brushing. In general, fine aggregate will produce a comparatively smooth surface of uniform color, while coarser aggregates will give greater irregularity in both surface and color, producing a somewhat rustic appearance.

Fig. 31.—Rubbed concrete surface treated with cement stain. Special mortar facing.

One of the chief advantages of finishing surfaces by brushing is the adaptability of this process to every class of concrete construction. Park benches, lawn vases, lamp posts and statuary of all kinds may be finished by this process, as easily as buildings.

38. Rubbed Surfaces.—Where it is desired to leave a smooth surface in the shape produced by the forms but to obtain a more finished surface than possible by washing with a float under which sand is used for cutting, the concrete may be finished, when it is at an age of from one to two days, by removing the form and rubbing the surface with a brick of sand, natural stone, emery, or carborundum (Fig. 31).

Where it is desired to finish concrete in this manner, the large pieces should be spaded back from the forms so that the face will contain little or no coarse aggregate. If a mottled

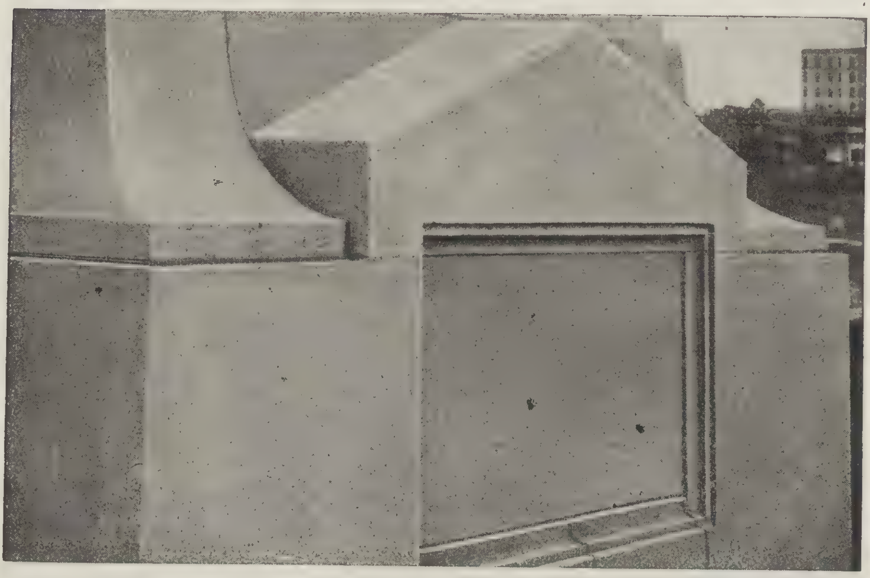

Fig. 32.—Brush-hammered surface.

surface is desired, it may be produced by a mortar composed of one part of Portland cement and two and one-half parts of white marble or limestone, either of which will rub to a very beautiful surface. While the rubbing is in process a thin grout composed of one part of cement and one of sand should be applied and well rubbed in. The work should afterwards be washed down with clean water.

39. Dressed Surfaces.—When concrete has hardened thoroughly it may be dressed in the same manner as natural stone (Fig. 32), although the stone cutter's tools require slight alterations to suit the need of the concrete. While this work is sometimes done upon concrete when it is two or three days old, the best results are obtained after it is about a month old. The great disadvantage of dressing concrete with a stone hammer at too early an age is that pieces of the aggregate will be knocked out from the cement mortar leaving unsightly holes, while if left for a few weeks they will become so thoroughly bonded that they will break under the hammer and give a uniform surface much the same as natural stone.

For this purpose the best tool is a special form of bush hammer designed to dress concrete, the points on the face of which are farther apart and larger than on the regular stone cutter's hammer. A three-pound hammer with four points is a good size for concrete work, although larger ones are frequently used. Another hammer which has been especially designed for dressing concrete is similar to a pick having five teeth on each end. This is made in two forms, one consisting of a steel head six inches long, bevelled at both ends, the other being in the form of a central cast steel head to which steel plates are bolted. In the latter form, the plates are removable, and when dull are replaced by sharp ones. Three-eighths inch crushed granite screenings were used for facing the exposed surface of the Connecticut Avenue Bridge, Washington, D. C., and the finish was obtained by bush hammering. Very desirable exteriors may be produced by bush-hammered panels finished with two-inch smooth borders as shown on the Piqua Hosiery Co's Building, Piqua, Ohio, a replica of which was exhibited at the Cement Show in 1914. By using this method all trouble in finishing corners is eliminated and the architectural design accentuated and improved. For finishing large surfaces a pneumatic hammer is used and produces a uniform finish, doing the work much more rapidly than where the tools are operated by hand.

40. Sand Blast Surfacing.—Sand blast is frequently used for finishing concrete surfaces on large construction. It removes the plaster effect left by the forms and produces a granular finish (Fig. 33). Sand blasting involves the erection of quite a large and expensive machine, forcing sand grains from a nozzle by pneumatic pressure and driving them against the surface of the wall with such violence that the sand cuts out the softer particles of the concrete against which it is thrown.

Upon a dense and thoroughly hardened surface, a $\frac{3}{8}$-inch nozzle may be used but if the surface is not thoroughly hard, say two or three months old, it is better to use a $\frac{1}{4}$ or even $\frac{1}{8}$-inch nozzle. Crushed quartz or sharp silica sand should be used for sand blasting. If a $\frac{1}{4}$-inch nozzle be used, the

FIG. 33.—Sand blast finish. No special facing.

sand should be screened through a No. 8 screen; if a $\frac{1}{8}$-inch nozzle is used the sand should be screened through a No. 12 screen. Concrete should never be subjected to sand blasting until it is at least one month old. A nozzle pressure of from fifty to eighty pounds should be maintained.

41. Colored Surfaces.—For artistic work the suggestions already made with reference to the selection, gradation. and mixing of aggregate will accomplish better results than any process of artificial coloring which may be adopted, However, this paper would be incomplete if some information were not included regarding the possibilities of producing artificially colored concrete work.

The coloring matter should never exceed five per cent of the weight of the cement and should be mixed with the dry cement before water is added. Nothing but mineral coloring matter should be used and the following table, taken from *Cement and Concrete* by L. C. Sabin, is generally accepted as the standard authority for amounts of different coloring materials.

COLORED MORTARS

Colors given to Portland Cement Mortars Containing two parts River Sand to One Cement

Dry Material Used	Weight of Coloring Matter to 100 pounds of cement			
	½ Pound	1 Pound	2 Pounds	4 Pounds
Lamp Black	Light Slate	Light Gray	Blue Gray	Dark Blue Slate
Prussian Blue	Light Green Slate	Light Blue Slate	Blue Slate	Bright Blue Slate
Ultra Marine Blue	....	Light Blue Slate	Blue Slate	Bright Blue Slate
Yellow Ochre	Light Green	....	....	Light Buff
Burnt Umber	Light Pinkish Slate	Pinkish Slate	Dull Lavender Pink	Chocolate
Venetian Red	Slate, Pink Tinge	Bright Pinkish Slate	Light Dull Pink	Dull Pink
Chattanooga Iron Ore	Light Pinkish Slate	Dull Pink	Light Terra Cotta	Light Brick Red
Red Iron Ore	Pinkish Slate	Dull Pink	Terra Cotta	Light Brick Red

There will be exceptional cases where it is necessary or desirable to color concrete surfaces after the work has been completed. For this purpose, cement paint should be used, several brands of which are now manufactured in a limited number of colors, by reputable companies.

42. Designs.—There remains only one feature of concrete surfaces to be discussed, and that is the production of mosaics or pattern work. The plasticity of concrete makes it lend itself particularly to the reproduction of beautiful designs of all sorts which may be secured in a variety of ways. For the more elaborate designs the pieces of marble, if that be the material selected, should be glued face down upon tough paper in the same manner in which floor tile are prepared for laying. This paper with the design upon it should be placed in the form and the concrete filled in and thoroughly rammed to place. After the forms are removed and the concrete allowed to harden, the paper should be removed by wetting, and the face of the finished design cleaned with the usual acid solution, three parts of water to one part of commercial muriatic acid.

Examination Questions

26. What objectionable feature have rich mortars?
27. If a brushed surface is desired, when should the concrete be brushed?
28. In what proportion should a solution for acid treatment be mixed?
29. What aggregate may be substituted for white marble to secure economy?
30. What will accomplish better results than any process of artificial coloring?
31. How may special aggregates be introduced to produce elaborate designs?

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THE UNIVERSITY OF WISCONSIN

CORRESPONDENCE-STUDY

PRACTICAL COURSE IN CONCRETE

COURSE 430

ASSIGNMENT 5

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CHAPTER IX

CONCRETE BLOCKS

43. Historical.—The use of concrete blocks is of ancient origin, and although it is the purpose of this assignment to deal essentially with modern practice, it will be interesting to know that blocks of various forms and sizes composed of material similar to the concrete of today were used in many of the monumental works of the ancient world, and may still be seen in southern Europe, well preserved after the lapse of centuries.

The introduction of concrete blocks in America was, like all other uses to which concrete has been adapted, coincident with the perfection of the rotary kiln and the consequent development of American Portland cement manufacture. Houses constructed of solid blocks, or of blocks separated by metal anchors and thus forming a hollow wall, may still be seen after a half century of usefulness; but these are examples of the infancy of an industry which only began to come into its own ten years ago. At that time the idea of making blocks in shapes designed for use in constructing hollow walls, to insure warmth in winter and coolness in summer—blocks impervious to moisture and of such weight that they could be readily made and laid—gained so strong a hold upon the popular mind that many people rushed into manufacture of concrete blocks without adequate knowledge of the nature of cement or of the methods necessary to insure success in any branch of the concrete industry. Fortunately, these conditions have corrected themselves, and the elimination of the ignorant and unscrupulous block maker will follow. Today the concrete block industry stands upon a firm foundation of experience and reliability, the comparatively new building material being one which, having proved its efficiency, has come to stay.

44. Utility.—The fire-resisting qualities of concrete are so well known that it is necessary only to call attention to the fact that the design of the concrete blocks excels all other forms of concrete in this respect (excepting double monolithic walls only), because of the vertical and horizontal air spaces within the wall, which so far prevent the transmission of heat that in numerous fires it has been observed by reputable witnesses that the exposure of one side of a well-built 12-inch concrete wall to an intense and prolonged heat did not even damage merchandise on the other side. Damage to the blocks themselves has usually amounted only to slight chipping due to the dehydration of the outer part, or facing, often applied in making blocks.

The same feature, namely the nonconductivity of an interior air space, results in a decided saving of fuel during the winter and increased comfort in summer, while it especially distinguishes the concrete block as the most suitable building material for tropical and semitropical climates.

While it is not only possible but commercially practicable to make concrete blocks of watertight texture, the interior air space makes "assurance doubly sure" during protracted rainy spells, and effectually safeguards from the sweating so objectionable in other types of construction. Wherever the type of block used affords a continuous horizontal and vertical air space, as in two-piece walls, furring may be eliminated.

45. Materials of Manufacture.—The first requisite to the manufacture of a good concrete block is suitable materials. The concrete block is a composite product and can be no better than its weakest ingredient.

The fundamental requirement is high grade Portland cement, which must be kept in dry storage until used. Cement which has become damp enough to harden must never be used in making concrete blocks. If proportioning is done by volume, the commercial sack of Portland cement may be accepted as one cubic foot. If, however, sacks are opened before proportioning, the cement increases in bulk so materially that it is necessary to proportion by weight. (A sack contains 94 pounds net.)

46. Sand.—The sand used in the mortar of a concrete block should be silicious, coarse, and clean. If screened from bank-run gravel care should be exercised to see that it is free from animal or vegetable matter. If foreign substances are present, they should be removed by washing the sand. The selection of aggregates and methods of determining their suitability have been given in a previous assignment.

47. Gravel or Broken Stone.—The coarse aggregate for concrete blocks should consist of gravel or broken stone. Choice between the two depends upon local availability and desired surface finish. Crusher-run broken stone should not be used until the dust has been screened out and the stone properly sized for proportioning. Bank-run gravel must be screened and reproportioned before using. This point can not be too strongly emphasized, as many failures are directly attributable to neglect of this requirement. Whether strength and density or economy and the saving of cement be the aim, the block maker can not afford to use unscreened bank-run gravel.

So far as strength is concerned, it is impossible to make a concrete block stronger than the aggregate of which it is in part composed. The ultimate strength is demonstrated when a fractured block shows the cleavage—and not the pulling apart—of the coarse aggregate.

As to surface finish, the possible variations resulting from choice of aggregate are numerous. The granites, marbles, white quartz, and gravel of variegated colors are increasingly popular for exposed surfaces. For the main portion of the block, necessarily cheaper, limestone is in most localities the best available broken stone aggregate. Sandstones are variable in strength and the softer ones do not make good concrete blocks. Hard, clean, gravel is often cheaper than broken stone and is equally desirable.

48. Proportioning.—When the materials have been selected, the next step will be their proper proportioning, and for this purpose, it is necessary to establish an arbitrary standard of sizes—the sand grains passing through a screen of $\frac{1}{4}$-inch mesh, and gravel or broken stone passing a 1-inch ring and being retained on a sand screen.

Under average normal conditions, a mixture of 1 part Portland cement, $2\frac{1}{2}$ parts of sand, and 4 parts of gravel or broken stone (expressed as $1:2\frac{1}{2}:4$) has been found most satisfactory for the body or main portion of all blocks. If it is desired to face the block with a finer material, the richness will be increased in proportion to the elimination of coarse aggregate, but 1:1½ is as rich as should be used for any face, while a 1:2 is better except in cases where decidedly fine texture such as tooled and scrolled work is desired.

49. Mixing.—No matter how carefully the materials may be proportioned, good concrete blocks can not be obtained unless the mixing is properly and thoroughly done. For important work it is both safer and cheaper to use a power-driven mixer of standard make and known efficiency. However, where the proposed work is not extensive enough to warrant the installation of a mixer, equally good results can be obtained from painstaking hand mixing, using a watertight platform, first spreading out the sand, then the cement—mixing both together thoroughly—then adding the water and shoveling until the mortar is of uniform color; after this the coarse aggregate, which has first been thoroughly wetted, should be added and the whole mass turned twice after this addition.

50. Consistency.—The water used should be clean and used in such quantity that a medium wet mixture will result. By this is meant one that shows rather an excess of water so that when a small portion of the mass is firmly pressed in the hand several drops of water will be released from the concrete. No other consistency of mix is now recommended because the dry mix resulted in almost certain failure and the flowing mix was commercially impracticable for small plants on account of the large number of molds and the consequent expense of equipment required.

51. Molds and Machines.—Blocks are made by tamping or pressing the concrete in molds designed for the purpose, and it is manifestly beyond the scope of this assignment to discuss the various machines individually. The choice of a machine is, in the main, a matter of price, stability of construction, and minor details of operation. Most machines provide for a block of convenient size and weight, penetrated by cores which, when withdrawn, leave the hollow space which gives the concrete block its peculiar efficiency. The machines operated by pressure instead of tamping generally make the two-piece blocks; that is, the blocks do not extend entirely through the wall as do the tamped hollow blocks.

Both processes—tamping and pressing—and both designs, hollow and two-piece blocks, are now accepted as good construction by engineers and architects, if the rules heretofore given relative to selection, proportioning, mixing, and consistency are observed. If they are disregarded, no machine can produce a concrete block which will be creditable to the maker or satisfactory to the user.

52. Curing.—The curing of concrete blocks is a very important part of the manufacturing process. The setting of cement, or its crystallization, is a chemical reaction, accelerated by heat and possible only in the presence of moisture.

If cured by water, blocks should remain in a closed room for 24 hours, after which they may be stacked under a shed with open sides. Blocks require frequent sprinkling for two weeks and are not ready for use until a month old. Moreover, their color is affected by the variation of moisture and heat caused by wind currents to which they are necessarily subjected in the open-air curing shed. To overcome these objections and to shorten the curing period, we strongly urge wherever possible the construction of a closed, steam-curing room, in which the blocks may be cured for 48 hours in a saturated atmosphere at a temperature of 100 to 130 degrees Fahrenheit. The time should be doubled in winter. Such curing will be more effective as the blocks will develop greater strength in ten days than air-cured blocks will in twenty-eight days. The color will more closely approach uniformity owing to the fact that each block thus receives the same treatment. The corners and facing of blocks will not be exposed to the usual injuries almost inseparably connected with setting green blocks in the yard. The saving of time and yard room is by no means an insignificant item. Steam curing makes it possible to operate the plant 12 months in the year.

53. Building Construction.—The different manufacturers of concrete block machines have evolved designs for corner-blocks, jamb-blocks, chimney-blocks, and other special members, according to the requirements of each particular system. These are generally well adapted to their intended usages. The block maker must bear in mind, however, that corners and jambs are subjected to greater wear and greater possibility of accident than are "stretcher" blocks, and suffer more exposure in time of fire; and consequently they require special care in making and will cost proportionately more. Accessories such as joist-hangers at floor levels and T-rods for securing roof plates are manufactured by several reputable firms and are advertised in the columns of current concrete publications.

Footings should be of poured concrete in which the lower course of the foundation wall may be imbedded. Concrete blocks 12 inches wide form an ideal cellar wall. This is ample thickness for the foundation wall of a two-story building. The walls of the first story may be of the same width, those of the second story reduced to 10 inches. Higher buildings will usually be constructed in cities or towns where thickness of walls is regulated by ordinance.

54. Appearance.—The possible variations in surface finish of concrete blocks afford almost unlimited opportunity to the block maker who remembers that concrete is a separate and distinct building material possessing possibilities beyond the range of those afforded by either brick or stone. If he grasps this fact, he will cease his efforts to produce a plastic and unpleasing counterfeit of the cheaper grades of stone work. He will learn that by proper selection of aggregate he can secure a surface which, if left plain and smooth, is as beautiful as a mosaic, or which roughened by brushing a film of cement from the surface of a newly-made block and washing the face so roughened with a 1:3 solution of commercial muriatic acid, will produce effects of startling originality and beauty.

CHAPTER X

CONCRETE FENCE POSTS

What has been said in Chapter IX regarding the general principles of concrete construction will apply with equal force to concrete fence posts and will not, therefore, require repetition.

The concrete fence post, like the concrete block, is a comparatively small unit manufactured for a particular purpose and thoroughly seasoned before being put to its ultimate use. Consequently, the same care must be exercised in the selection as well as in the proportioning and mixing of materials.

55. Consistency.—Slightly more water is necessary in mixing concrete for fence posts than is used for blocks, owing to the different process of manufacture. A quaky mixture, which is wet enough to be just beyond the possibility of tamping, is used for posts—compactness in filling the molds being secured either by agitating the concrete, by stirring it, or by jarring the mold.

56. Reinforcement.—In but one other respect does the concrete fence post depart from the process of manufacture applied to the concrete block. The peculiar duties demanded of the concrete fence post subject it to strains beyond the lateral resistance of a plain concrete member having such a small cross section.

To overcome the strains and thrusts peculiar to the duty demanded of the fence post, reinforcing wires or rods of steel are introduced, and it is very important both as regards the strength of the post and the saving of material that the reinforcement be properly placed. By imagining a post constructed of rubber and considering how such a post would act if bent far over to one side, the theory of reinforcement is easily pictured to the mind. A rubber post would manifestly be stretched on one side and pinched on the other, so we say that one side of the post will sustain tensile stress while the other will be subject to compression. As is well known, concrete is strong in compression and weak in tension, or resistance to pulling strains; hence, on the side that is stretched we introduce just steel enough to balance or develop the opposing compressive strength of the concrete. Thus we secure maximum efficiency from both the concrete and the steel. We are unable to tell in advance which of the four sides of a post will be called upon to withstand the thrust; therefore, we usually imbed at each corner of the post, $\frac{3}{4}$-inch from the surface, a $\frac{1}{4}$-inch steel rod, twisted bar or wire. In this way a direct stress from any side is resisted by two rods acting in unison.

57. **Dimensions.**—Posts are usually made 7 feet long, 3 inches square at the top and 5 inches square at the bottom or they may be made 4 inches square at the top and 4 inches by 6 inches at the bottom. The dimensions first given are usually preferred, on account of the taper on all four sides making it easy to fasten the line wire by merely tying a small wire to it and making it taut around the post. The method of making holes through posts is objectionable because it weakens the posts and also because such holes establish an arbitrary place for fastening line wires which is frequently inconvenient and often interferes with uniformity in fence construction. This last objection is also a fault of staple and T-shaped fastening devices of metal which are, moreover, liable to failure from rusting on account of exposure to the weather.

58. **Molds.**—The preparation of "knock-down" molds (Fig. 34) using head pieces and clamps—the lumber being protected from warping by painting with equal parts of boiled linseed oil and kersoene—is a simple matter and will cause no inconvenience to the ordinary manufacturer. If he has a large amount of fence to build, however, it will probably be more profitable for him to purchase a set of steel molds from one of several firms now manufacturing them in sets, known as "gang" molds, which permit making from four to twelve posts at one operation.

Whether a mold be made of steel or lumber, the essential points are that its sides shall be strong enough to remain true under the lateral pressure incident to filling the mold compactly, and that the mold be so constructed that the long, slender concrete post may remain undisturbed until the concrete has attained sufficient rigidity. This will usually require a week. No post should be used until it is a month old.

Hence, most molds are arranged to unclamp so as to be easily removed from the post, leaving it lying on the bottom board. While there are machines for making posts in vertical position, it will generally be found more practicable to make them horizontally, placing the reinforcement in the proper places while filling the mold.

59. Cost.—Under average conditions the cost of the materials used in a concrete post will be twenty-three cents.

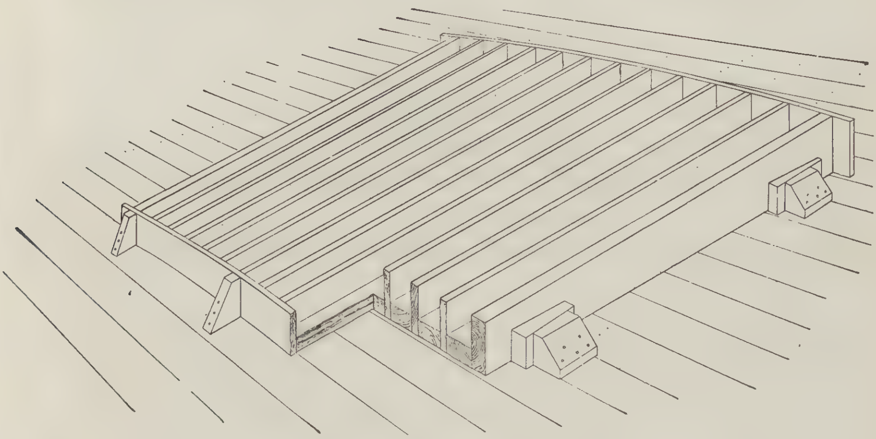

FIG. 34.—Home made post molds.

Cedar, white oak, chestnut or locust posts can scarcely compete as to price anywhere, and when the greater life of a concrete post due to immunity from fire, insects and rot is considered, its marvelous popularity is easily understood.

60. Corner Posts.—Corner posts will receive more strain than line posts and require additional reinforcement. Eight by eight inches without taper, reinforced by four $\frac{9}{16}$-inch steel rods or other reinforcement of equal cross section, makes a substantial corner post.

Braces may be made in homemade molds 5 inches square and 10 feet long, with proper bevel at the end and four $\frac{3}{8}$-inch steel rods for reinforcement. Lugs may be cast on the corner posts to engage the braces or a mortise made in the face of the corner post.

On account of the small number required, gate posts will warrant additional cost and should be plain but massive,

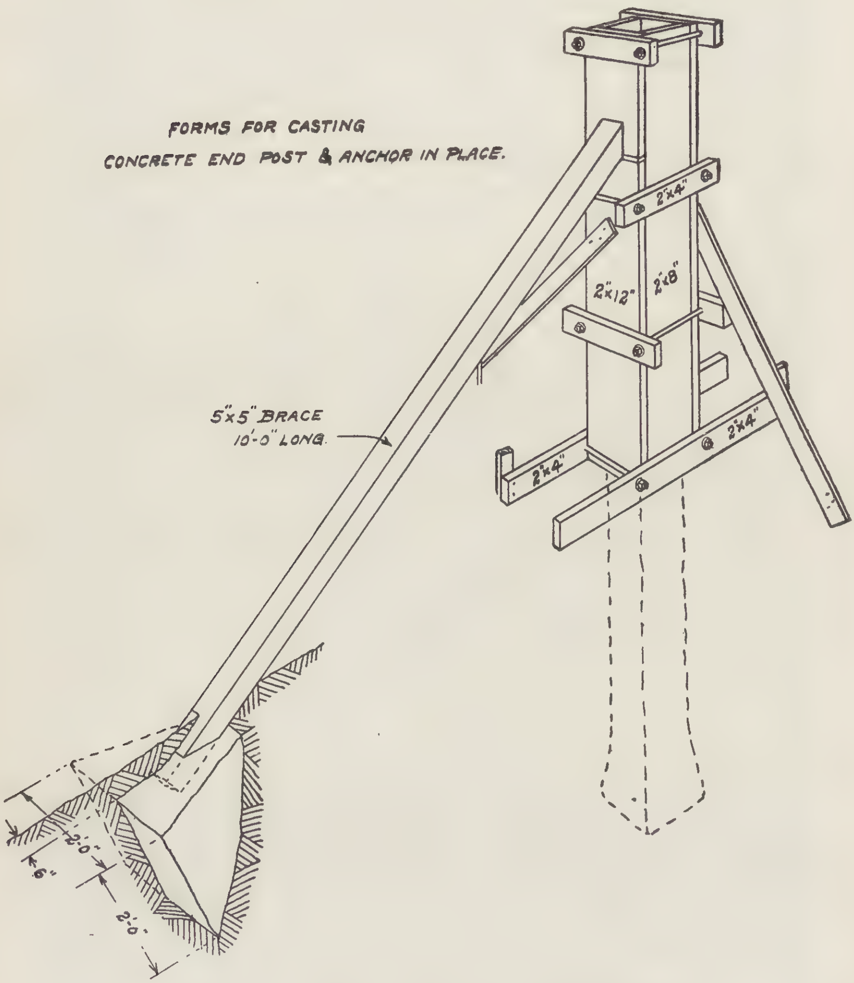

Fig. 35.—Concrete end post with braces in place.

thereby materially adding to the appearance of the fence and indirectly enhancing the value of the farm.

The weight of a large post will make it difficult to handle, and on this account the corner posts are often molded in place. This method is advisable where the post can be properly cured before any strain is put upon it. When the sides of the post hole will stand without caving the earth will serve for a form below the ground. Therefore the hole should be of the size and shape desired for the post. It should be dug with vertical sides and enlarged somewhat at the bottom for anchorage. The concrete should be deposited carefully so that no dirt will be knocked into the hole and mix with the concrete. A form such as is shown in Fig. 35 may be used above ground. The method of bracing shown is recommended as the anchor for the brace can best be cast in place. The brace itself should have been previously molded and cured sufficiently for safe handling. It should extend into the post at least 1 inch and should be well imbedded in the anchor at the other end. The earth will serve as a mold for the anchor and the hole should be dug in the shape shown in the illustration. The concrete for the anchor should not come closer than 6 inches to the top of the ground, but should extend below the frost line. As practically all the tension in the wire fence is transmitted to the end post, there is a strong tendency to overturn the post or break it off at the surface of the ground. While this tendency can be overcome by massive construction or heavy reinforcement, it is not economical and satisfactory results can be obtained by using braces such as are shown in Fig. 35.

Examination Questions

32. What are the essential requisites in the manufacture of concrete block?
33. State the size of sand, gravel or broken stone necessary for concrete block.
34. What proportions should be used for the main portion of all block; what for the face?
35. What consistency of mixture should be used in block making?
36. What system of curing is preferable?
37. What is the usual method of reinforcing concrete fence posts?

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CHAPTER XI

CONCRETE SIDEWALKS

61. Economy and Durability.—When compared with any other material suitable for sidewalks, the low cost and permanence of concrete have resulted in its almost universal adoption in enterprising communities for constructing sidewalks. But it is essential that no one engage in the construction of anything so important to the welfare of the community as sidewalks, without thoroughly investigating the principles on which success depends, and becoming entirely familiar with the best modern practice.

62. One and Two-course Walks.—In the early days of concrete walk construction it was the universal practice to use a base of coarse concrete over which was spread a mortar top varying from $\frac{3}{4}$ inch to 1 inch, made of cement and sand, or cement and stone screenings. This top or wearing surface was usually troweled to a "glassy" surface, under the belief that a very smooth surface made a stronger appeal to the public eye. Very serious objections to this practice have arisen. Not only has a surface so finished been found slippery and dangerous to pedestrians, especially in winter weather, but in cases of careless construction, the imperfect bond between the top and base has resulted in the two separating, causing ultimate failure of the walk.

In the one-course construction, recently introduced, a single mass (or thickness) of well-made concrete is used, and the surface instead of being troweled is finished with a wood or cork float, resulting in an even but not smooth tread, which overcomes the objection of the slippery troweled surface. Using one mixture throughout the walk, all of which is placed and tamped at one operation, does away with any possible line of cleavage and consequently insures absolute permanency, the entire slab being a homogeneous unit.

Some sidewalk contractors still feel that a saving in cost may be effected by using a coarser material for the base.

To correct this impression, data have been collected showing the comparative cost of one and two-course walks.

In one-course walks $4\frac{1}{2}$ inches of the richer mixture is undoubtedly equal in strength to 5 inches of the two-course walk.

The following table gives the cost of materials used in the construction of 100 square feet of sidewalk and is based upon the following prices:

Portland cement $1.50 per barrel net; sand $1.25 per cubic yard; gravel $1.50 per cubic yard. (It should be understood that on account of freight on long hauls the cement will sometimes cost twice as much as shown.)

	Mixture	Bbls. Cement	Cu. Yds. Sand	Cu. Yds. Gravel	Total cost Materials
5-inch two-course......	1:2½:5 base 1:1½ top	2.52	.80	1.21	$6.79
4½-inch one-course	1:2:3	2.42	.73	1.08	6.16

63. Materials.—In the construction of concrete sidewalks, as in all other concrete construction, a standard brand of Portland cement should be used.

Fine aggregate should consist of sand, crushed stone (free from dust) or gravel screenings, graded from fine to coarse and passing a screen of $\frac{1}{4}$ inch mesh. It should be clean and free from foreign matter. On account of resistance to abrasion, granite screenings have been used extensively for the wearing surface where there is considerable traffic.

Coarse aggregate should consist of clean, well-graded gravel or broken stone varying in size from $\frac{1}{4}$ inch to $1\frac{1}{4}$ inches. Bank-run gravel should never be used without screening and remixing in the proper proportions; it usually contains an excess of fine material rendering proportions uncertain and indefinite. If the gravel contains loam, clay or other foreign matter, it should be washed before use.

64. Proportions.—In the construction of one-course walk, the materials should be mixed in the proportions of 1 sack of Portland cement, 2 cubic feet of fine aggregate, and 3 cubic feet of coarse aggregate.

In the construction of two-course walk, the concrete for the base should be mixed in the proportions of 1 sack of Portland cement, $2\frac{1}{2}$ cubic feet of fine aggregate and 5 cubic feet of coarse aggregate.

In two-course work, the top or wearing surface should consist of mortar mixed in the proportions of 1 sack of Portland cement to not more than 2 cubic feet of fine aggregate.

65. Mixing.—The importance of thoroughly mixing the materials in the construction of concrete sidewalk can not be too strongly emphasized. Whenever possible, a power batch mixer should be installed. On a contract of any considerable size, power mixing will be cheaper than hand mixing, and every contractor has found the work of mixing by hand so laborious that the fatigue of the men has a marked effect upon the quality of the concrete.

66. Concrete Mixers.—Batch mixers consist mainly of a rotating drum driven by steam, gasoline engine, or electric motor. Both the shape of the drum and the use of inside deflectors are relied upon to secure thorough mixing. The order in which the material is discharged from a batch mixer is independent of the order in which the materials are placed in the mixer. Hence, all materials required for one batch are dumped into the mixer at one time, no attention being given to the order in which they are introduced. After the drum has made a few revolutions water in measured quantity should be added and the mixing continued for a specific time, or definite number of revolutions. A mixer must always be run slowly to secure the best results.

Continuous mixers consist mainly of a number of hoppers for the several materials, placed over one end of a semicircular trough containing blades or vanes fixed to a rotating shaft. Motive power is generally supplied by a gasoline engine or an electric motor. Dry materials are fed automatically from the hoppers into the trough, where water is added and the mass carried along by the blades to the discharge end.

Mixers of the batch type give better results because the mixing is under the operator's control, and may be continued until the materials of each batch are perfectly mixed. Moreover, the measuring of materials can be regulated positively, whereas with continuous mixers variation in the amount of moisture in the sand, fluffiness of the cement or "arching" of material in the hoppers will vary the relative proportions of the different materials in the mixture.

67. **Consistency.**—Concrete used for one-course walk should be wetter than a mixture used for the base of two-course walk, sufficient water being used to make a quaky consistency. Enough water should be added so that when the concrete is placed and lightly tamped the mortar will flush to the surface and make finishing easy.

Mortar for the wearing surface of two-course walk should be mixed to such consistency that it will spread under a straight-edge resting on the forms, but should not be wet enough to cause excess water to stand on the surface after finishing with a wood float. If surplus water appears on the top of the mortar, after floating, it must be taken up with a sponge or mop. The practice of throwing dry cement on a finished surface to take up surplus water, should be condemned.

68. **Subgrade.**—"Subgrade" is the term applied to the surface of natural soil as prepared to receive the subbase, or to receive the sidewalk directly where a subbase is unnecessary. The subgrade should not only be level, but should be practically uniform in density. If there are any holes or soft spots in the ground, they should be filled, and the filling be tamped. In the case of a fill the earth should be tamped in layers not exceeding 6 inches in thickness which should extend at least one foot on each side of the walk, the sides having a slope of 1 to $1\frac{1}{2}$. The subgrade should have a slope (toward the curb on city streets) of $\frac{1}{2}$ inch to the foot, to allow for drainage, and should be 11 inches below the finished surface of the walk, except when no subbase is required, in which case the subgrade should be 5 inches below the finished surface of the walk.

69. **Subbase.**—The subbase is the foundation for the walk; it is laid on the subgrade and is immediately underneath the concrete base. The subbase should consist of broken stone from which the fine particles have been removed by screening, coarse gravel, cinders or blast furnace slag, the idea being to secure a porous material through which

water will readily drain. The subbase should be 6 inches in thickness laid directly on the subgrade, and thoroughly tamped. On fills, the subbase should be the full width of the fill and the sides should have the same slope as the sides of the fill, namely 1 to $1\frac{1}{2}$. Wherever the climate is such that freezing occurs during the winter, the subbase is an essential part of concrete walk construction. Only where there is no danger of frost, or where there is perfect drainage, can the subbase be safely discarded and the concrete base be laid directly upon the subgrade.

70. Forms.—Forms may be made from 2-inch lumber, the width being determined by the height of the walk, usually $4\frac{1}{2}$ inches in the case of one-course walk and 5 inches in the case of two-course walk. Thirty-six square feet should be adopted as the maximum area of a single slab and 6 feet as the greatest dimension permissible. Places where the cross pieces join the side forms should, in two-course construction, be very plainly marked, so that when the wearing surface is laid, the final grooving may coincide with the joint in the base. Forms must be kept well cleaned and must not be used on a new job if concrete from the last job is sticking to the face. Several well-designed steel forms are now manufactured, which may be advantageously used whenever the area of walk to be constructed will justify the initial expenditure. Construction will be more uniform if such forms are used, and in the long run they will more than pay for themselves.

71. Placing.—In constructing one-course walk the concrete should be placed and tamped to a thickness of $4\frac{1}{2}$ inches. Steel tampers are used, varying from 6 by 6, to 10 by 10 inches. For the finishing of one-course walk a steel tamper with a face 8 inches square is preferable. A commercial type has pyramidal projections, which force the coarse aggregate below the surface leaving the finer particles at the top, ready for finishing with a wood float. A steel trowel should never be used for finishing any walk.

In constructing two-course walk, the concrete should be placed and tamped to a depth of $4\frac{1}{4}$ inches, allowing $\frac{3}{4}$ inch for the wearing surface, which will be mixed separately, and must be placed as rapidly as possible after the placing of the base. If any considerable time elapses between placing the base and laying the wearing surface thereon, the bond between the two will be in danger.

Finishing of the wearing surface or face may be done in several ways, and while the use of a wooden float is always preferable, there are those who still wish the surface troweled. If troweling is done, it should be as lightly as possible, in order to prevent the formation of fine cracks and checks as well as a glassy surface.

The wearing surface should be cut through with a trowel directly over the joints in the base, and the groover run over the surface along the joint. Sides should be finished with an edger having a $\frac{1}{2}$-inch radius.

If the laying of slabs is continuous, the cross pieces should be removed when a slab has been completed, and the material for the next slab placed immediately. In order to insure perfect joints between slabs it is becoming quite common to construct slabs alternately. In this way slabs are allowed to remain until the cement has partially hardened before the cross pieces are removed and the material for adjoining slabs placed. In this manner the slabs form distinct units and are not so likely to break in case of any future settlement in the foundation. The same result may be attained by using metal cross pieces remaining in place until the concrete has partially hardened.

72. Coloring.—If it is desired to vary the natural color, the use of lamp black, iron oxide, or any mineral coloring matter is allowable, provided it is thoroughly mixed with the dry sand in quantities not exceeding 5 per cent of the weight of the cement. Accuracy in measurement and thorough mixing are extremely necessary if uniform color is to be expected.

73. Protection.—As soon as the concrete has hardened sufficiently to prevent the surface from being pitted, it should be sprinkled with clean water and kept wet for at least four days and not be exposed to traffic until thoroughly hardened.

74. Freezing.—Under ordinary circumstances the construction of concrete walk during freezing weather is not advocated. If circumstances make it imperative to proceed with the work at such time, the requirements on all concrete work, such as heating the water and aggregates must be observed, and precautions must be taken to protect the work from freezing for at least five days after placing the concrete. It is essential that both the subgrade and the subbase should be free from frost when the walk is laid.

75. Expansion Joints.—Expansion joints should be 50 feet apart and $\frac{1}{4}$ inch wide. They should be filled with tar, prepared felt or some other material which will retain elasticity under changing atmospheric conditions.

76. Precautions.—Walks should be grooved where crossed by driveways and if it is a two-course walk, the wearing surface should be two inches in thickness at the driveway crossing.

Where a new walk joins an old one and either the grade has been changed or the old walk was not properly laid to grade, laying an entire slab at the grade necessary to joint the two walks will avoid the unpleasant and dangerous beveling that is sometimes seen.

In laying a walk around trees, 6 inches clearance should be allowed to provide for future growth. The character of the trees should be investigated, as trees having lateral roots on or near the surface of the earth are almost certain to cause trouble at some time.

CHAPTER XII

CONCRETE CURB AND GUTTER COMBINED

Combined curb and gutter is recommended only for streets which are not to be improved by permanent pavement. Where a street is merely graded, or surfaced with disintegrated granite or some similar material it is necessary to construct concrete gutter in connection with the curb.

77. Similarity to Sidewalk Construction.—Concrete curb and gutter is closely associated with concrete sidewalk construction, not only on account of its position when placed but because the materials and method of using them are much the same.

What has already been said in Chapter XI in regard to cement, selection of fine aggregate, and selection of coarse aggregate for concrete sidewalk, applies equally well to concrete curb and gutter.

Materials must be mixed with the utmost thoroughness, and a batch mixer should be used whenever possible. If the mixing must be done by hand, it should be upon a watertight platform, according to the best methods, which involve spreading the sand, then the cement, mixing them until of uniform color, incorporating the coarse aggregate, adding water, and turning the entire mass at least three times or until of uniform consistency.

As in the case of concrete sidewalk, concrete curb and gutter must be carefully protected after placing, and must be kept thoroughly wet for the first four days.

Precautions must be taken when necessary to protect from frost for a period of five days, and both the subbase and subgrade must be entirely free from frost at the time of placing the concrete.

The concrete should be mixed to a quaky consistency, so that water will flush to the surface under slight tamping. Mortar for the wearing course must be of such consistency that it will not require tamping, but can be easily spread into position.

All of the above requirements are substantially the same as for the construction of concrete sidewalk.

78. Subgrade.—The subgrade must be level, firm, and free from soft places. If filled, the earth must be tamped in layers not exceeding 6 inches in thickness. Whether it is a fill or an excavation, the surface must be finished 11 inches below the established grade of the gutter.

79. Subbase.—Upon the subgrade must be laid the subbase consisting of suitable porous material, such as slag, cinders, large gravel or broken stone from which the finer pieces have been screened, and this material must be thoroughly compacted and rolled to a thickness of 5 inches so that its surface will be 6 inches below the established grade of the gutter. The above measurements are given with reference to the grade of the gutter, which is itself 6 inches below the grade of the curb.

80. Construction.—In combined curb and gutter, the depth of the back will be 12 inches, the depth of the face 6 inches, the breadth of the gutter from 16 inches to 24 inches, and the sections from 5 feet to 8 feet in length, with $\frac{1}{2}$-inch expansion joints occurring every 150 feet. Expansion joints should be filled with tar, prepared felt or other suitable material which will retain elasticity under changes of temperature, and the abutting corners should be rounded. The necessity for liberal expansion joints between the curb and the sidewalk deserves especial emphasis, as cases of concrete curb and gutter failing through lateral pressure from expanding sidewalk are numerous and unnecessary.

Two-inch lumber may be used for forms except at street corners where the radius should not be less than 6 feet, and may be provided for by substituting metal strips in place of the usual lumber. Metal cross pieces must be provided between sections, and their positions distinctly marked upon the front and back pieces of the forms in order that the wearing course when applied may be cut through and grooved exactly above the joint in the concrete base. The slope of the gutter may be regulated and maintained by using an ordinary wooden level with a nail driven in the bottom at one end, and extending out a distance equal to the required pitch. The street side of the gutter will be raised at the approach to street crossings, so that it may conform to the grade at the sidewalk crossing.

A number of very satisfactory varieties of forms are now manufactured from sheet steel. They are not only more durable than wood, but are held in place by templates, which do away with the necessity of cross pieces and eliminate the clamps required in connection with wood forms to hold in place the board forming the face of the curb. This is a distinct advantage, affording considerable saving of time, while the templates themselves satisfactorily divide the finished curb and gutter into sections, which is a point of considerable importance in view of the disaster which might otherwise follow a foundation failure.

81. Placing.—In the construction of two-course concrete curb and gutter, the concrete should be mixed in proportions of 1 sack of Portland cement, $2\frac{1}{2}$ cubic feet of fine aggregate, and 5 cubic feet of coarse aggregate. Mortar for the wearing course should be mixed in the proportion of 1 sack of Portland cement to 2 cubic feet of sand or other suitable fine aggregate.

Concrete mixed in the proportions above specified, should be deposited in the forms and thoroughly rammed to place, allowing $\frac{3}{4}$ inch for wearing surface, the latter to be applied as quickly as possible in order to secure an effective bond between the base and the wearing surface.

Three different methods of applying the wearing surface have been used. The first consists in applying the mortar to the top of the gutter and the top of the curb, and as soon as these have been finished, removing the form from the face of the curb and troweling the mortar down the vertical face. This method is unsatisfactory for several reasons. It often results in the face of the curb being but thinly covered, it necessitates the use of too dry a mixture on the vertical face, and results in excessive troweling which develops hair cracks and checking on the wearing surface. The second method consists in plastering on the inside of that portion of the form making the vertical face or street side of the gutter, $\frac{3}{4}$ inch of plastic mortar, the form being filled with concrete at the same time so that the introduction of the mortar and concrete is practically simultaneous. When the form lacks $\frac{3}{4}$ inch of being filled, the top is then filled with mortar. After removing the forms, the only work remaining is the finishing of corners. A $1\frac{1}{2}$-inch radius is given to the curb on the street side and the intersection of the curb and gutter; all other edges are rounded to a $\frac{3}{8}$-inch radius unless protected by metal. The third method differs from the second only in slipping a 1-inch board, 6 inches wide and surfaced on one side, inside of that portion of the form making the face of the curb. When the form has been filled with concrete this board is withdrawn and the space left by its withdrawal is then filled with plastic mortar. The second method will usually secure a better bond between the base and the wearing surface.

Excessive troweling is too often practiced in finishing the wearing surface of concrete curb and gutter. A large part of the finishing may be better accomplished by the use of a stiff fiber brush which will give a more durable surface less likely to develop hair cracks and checking.

82. One-course Work.—Concrete curb and gutter has not yet been so extensively constructed after the one-course method as has one-course sidewalk, but one-course construction is likely to supersede two-course ultimately to a great extent on account of greater durability, more permanent wearing surface, and the saving in time and labor. In one-course work the concrete should be prepared in proportions of 1 sack of Portland cement, 2 cubic feet of fine aggregate and 3 cubic feet of coarse aggregate, using a tamper with pyramidal or similarly-formed projections that will drive the coarse aggregate below the surface and leave the mortar on top for finishing with a wood float.

CHAPTER XIII

CONCRETE CURB

In all cases where there is a probability of permanent road improvement, concrete curb should be constructed without gutter, as the gutter will be provided by the slope of pavement adjoining the curb. By this method of construction, the longitudinal joint separating the pavement from the curb is at the extreme edge of the pavement and the objectionable longitudinal joint between pavement and gutter is eliminated.

83. Method of Construction.—Building concrete curb without gutter is very simple. There is no occasion for making the wearing surface richer than the main body of concrete; consequently the entire curb should be of 1:2:3 concrete finished with a wood float, as recommended for one-course curb-and-gutter work.

For constructing concrete curb without gutter, the subgrade should be finished 30 inches below the established grade of the work. The subbase should occupy 6 inches, making its surface 24 inches below the established grade of the curb. Concrete curb should be 12 inches wide at the base, 6 inches wide at the top, 24 inches high, and have a batter on the street side of 1 to 4.

Examination Questions

38. Which is the cheaper, one-course or two-course walks?
39. In what proportions should concrete be mixed for constructing one-course concrete walks?
40. To what is the term "subgrade" applied?
41. In constructing two-course walks, what should be the respective depths of concrete and wearing surface?
42. What quantity of mineral coloring matter is allowable?
43. Where there is a probability of concrete road improvement, how should concrete curb be constructed, and why?

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CHAPTER XIV

CONCRETE PAVEMENTS AND ROADWAYS

Street and highway pavement, as one of the more important applications of concrete, is now receiving recognition because the public is educated as never before to the uses and advantages of concrete in many types of construction. January 1, 1914, there was approximately 19,584,000 square yards of concrete pavement in the United States, practically all of which had been laid within four years. At first thought this statement would suggest that concrete as a paving material had not yet been subjected to sufficient age test to demonstrate its permanence and efficiency. Such, however, is not the case, as four blocks laid in Bellefontaine, Ohio, in 1893, and one-half block laid in Detroit in 1900, still giving effective service, silence argument against the durability of well-constructed concrete pavement.

In order to comprehend the nature and significance of the concrete highway movement, a concrete street or highway pavement may be compared to a sidewalk, though wider, thicker, and stronger. Increased width, thickness, and strength are details of construction introduced to adapt those principles which have proved successful in sidewalk construction to the greater wear of horse-drawn vehicles and motor traffic.

84. Similarity to Sidewalk.—Not many years ago concrete began to supplant other materials for sidewalk construction. The efficiency of concrete sidewalk was recognized immediately, and many people who were ignorant of the use of cement at once engaged in laying concrete sidewalks. As might be expected, results were disastrous and before long the failure of concrete sidewalks was heralded every-where. But the blame was soon located and the fault was found to be in ignorance of requirements or careless workmanship rather than in the material itself. Careful workmanship ultimately established the claim of concrete as the logical material for building sidewalk. Time has now justified that verdict and concrete pavement now profits by lessons learned from experience with concrete sidewalks. In some instances the same trying experiences that were encountered with concrete sidewalk have been met with in concrete pavement, but wherever a defect has appeared in concrete pavement investigation has proved that either the aggregates were poor or the construction faulty. Concrete pavement is no longer an experiment; with standardized practice, success is assured.

85. Importance of Maintenance.—The science of road building consists in getting the greatest number of miles of permanent highway for the smallest number of dollars. Ultimate cost, however, is not measured by the cost of construction alone. Maintenance is the real gage of economy in road building, as the upkeep of certain types of pavement in comparatively few years will equal or exceed the cost of constructing concrete pavement on which the annual cost of maintenance will be so small that it becomes a negligible factor.

86. New York's Experience.—Last year conditions upon New York State Highways became so bad that Governor Glynn sent a special message to the Legislature, drawing attention to the heavy cost of maintaining macadam roads under modern traffic conditions. Governor Glynn found the annual cost of maintaining macadam roads to be $1,000 per mile and the life of the macadam wearing surface only ten years. Evidently Governor Glynn's arguments convinced the New York State Highway Commission that concrete is cheapest in the long run, as the Highway Commission, which was then opposed to the use of concrete, has let contracts for more than 217 miles of concrete highway.

In the September issue of "New York Highway News," which is published by the New York State Highway Commission, George A. Ricker, First Deputy Commissioner, New York State Department of Highways, says:

"One of the most important changes of type of road called for by our standard specification is that of the first-class concrete pavement where a mixture of one part of Portland cement, one and one-half parts of sand, and three parts of stone is called for. In these requirements and in the other directions of this specification we have adapted to our uses the type of concrete road which has proved generally to be a success as built in other parts of the country. By a very careful supervision and inspection of contracts under this specification we believe we are getting permanent and desirable concrete pavements that will endure and give general satisfaction under the heaviest traffic with the minimum cost of maintenance."

87. Modern Traffic Conditions.—Concrete pavement slightly exceeds macadam in first cost, but the difference in upkeep is so strongly in favor of concrete that the argument for macadam is unsupported. Macadam and gravel were fairly satisfactory materials for paving at one time, but traffic conditions have changed and more permanent construction is now required to withstand the wear from rapidly-driven automobiles and heavily-laden motor trucks. Modern traffic conditions will ravel any pavement in which the particles are not held in place by a firm binder. Sand-cement mortar, as used in concrete, has already proved itself a successful binding material, fulfilling the requirements of present-day traffic, while macadam subjected to motor-vehicle traffic is rapidly filled with holes, bumps, and ruts, unless constantly kept in repair. Low cost of maintenance will soon offset the apparently high initial cost of a permanent pavement. The problem of maintenance is most easily solved by building concrete roads in the beginning, as they require little or no expenditure for upkeep.

88. Wayne County, Michigan.—Final utility of a road material is determined by permanence and durability. Concrete has been the principal road-building material used by the present commissioners of Wayne County, Michigan, where the roads are constantly referred to as an example of highway efficiency. The commissioners state that their sole aim is to provide the county with durable, permanent roads. They are firmly convinced that concrete roads have accomplished the object sought and that this type of road is the coming one. These officials took a wise view of the road question at the very start; they realized that road building should be planned not simply for this year, nor for next year, but for the future as well. Their manner of handling the road question was governed by the same foresight that a successful manufacturer would use. They regarded the road business as a permanent one, the ultimate success of which lies in the future.

Although concrete road building as first practiced in Wayne County was somewhat experimental, the commissioners have devised and introduced several details of construction which add materially to the life of concrete roads. They are now using concrete richer in cement than heretofore, more stringent specifications as to qualities of gravel and sand, and increased depth of concrete, so that fewer than six inches are not used. Steel protection plates are placed at every expansion joint. These roads have attracted the attention of county commissioners, engineers, public officials, and private citizens throughout the country, and as a consequence numerous other counties have adopted the Wayne County type of concrete road construction, with excellent results.

89. Ohio Flood.—Permanence of concrete as a road paving material was effectively demonstrated in the Ohio flood of March, 1913. On the Jackson Pike in Ross County, beginning two miles southeast of Chillicothe, a concrete road extending one mile in a southeasterly direction to the Scioto River, was built in the fall of 1912. This pavement is 16 feet in width, 5 inches thick at the sides and 7 inches in the center; the total cost was $11,518.62. Although submerged under 15 feet of water during the flood, the road has never heaved nor moved out of alignment. The shoulders of the road, consisting of 5-inch rip-rap, were turned over into the edge of a corn field, and the space intervening between the concrete and the overturned rip-rap was filled by sand, which the water carried along and deposited in the chasm.

90. Safety First.—Safety is a quality of concrete pavement which strongly recommends this type of construction for universal use in town and country. Horses are not injured by hard roads but by irregularities and loose stones upon the surface; and the smooth but not slippery surface of concrete affords the horse a sure foothold. This even surface lengthens horses' lives by preventing wrenching of knees and shoulders. Concrete pavement also presents to occupants of the automobile absolute security against skidding. Many of the worst accidents of automobiling have resulted from skidding of unprotected rubber tires on roads constructed of material that becomes slippery in wet weather.

91. Sanitation.—Concrete roads are always sanitary because they neither absorb liquids, nor raise dust. Hence, the nose of the driver is not offended by nauseous odors, nor are his eyes and lungs filled with the time honored "dust of travel."

92. Uniformity.—In all seasons and under all conditions of weather, concrete roads act the same. They do not melt and run in summer, nor do they freeze and break in winter. Never plastic, never brittle, they are always dependable. Concrete is not harmed by freezing and thawing after it has become thoroughly hard. Slight expansion and contraction due to temperature changes are amply cared for by transverse expansion joints provided at intervals varying from 25 to 50 feet.

93. Construction of Concrete Highways.—Concrete highways are ordinarily constructed as a strip of concrete varying in width from 10 to 18 feet, which bears the burden of traffic, while shoulders of gravel or other inexpensive material are provided for protection and for the use of passing vehicles. In this manner a permanent roadway is secured at minimum cost. This method could not, of course, be utilized for city pavements where the entire street must be uniform from curb to curb.

94. Reinforcement.—If the pavement is more than 20 feet wide, reinforcement should be used to prevent cracks from stresses due to temperature changes or defects in the subgrade. Wire mesh fabric is most commonly used.

95. Crown.—As the surface of concrete drains easily, a crown of $\frac{1}{100}$ of the width of the pavement or roadway is sufficient, and being less than the crown ordinarily used with other types of paving materials, tends to distribute traffic over the entire width of the pavement, offering added convenience to travelers and resulting in uniform wear. If the earth on which the concrete pavement is laid is made level, the entire crown will be made in the concrete. If the entire crown be made in the earth, the concrete will be of uniform thickness, merely transmitting the contour from foundation to surface. If part of the crown be provided in the earth, the remainder will be made in the concrete. In alley paving the earth is usually dished and concrete made of uniform thickness from side to side, leaving the surface lower in the middle than at the sides.

96. City Pavements.—Street pavements, alley pavements, and country highways possess so many points of similarity that standard methods of constructing street pavements will first be discussed after which points of variance in constructing alley pavement and country highway will be noticed.

97. Subgrade.—The bottom of an excavation or the top of a fill made for the purpose of laying the concrete pavement is known as the subgrade. Choice between flat or crowned subgrade depends upon whether concrete is to be laid of uniform thickness or is to be thicker in the middle of the street than at the sides. Sometimes a portion of the crown is provided for in the subgrade and a portion in the concrete. In streets where the pavement is less than 20 feet wide the subgrade should be flat and the crown obtained by increasing the thickness of the concrete, rather than by laying the pavement of uniform thickness on a crowned subgrade. On wider pavements, where reinforcing is used, a saving of material may be effected by making the crown in the subgrade and laying concrete of uniform thickness.

All soft or spongy spots must be filled and thoroughly compacted after which the entire subgrade must be finished to a firm, unyielding surface by rolling with a roller weighing from 5 to 10 tons. Corners and other places inaccessible to the roller should be tamped with a 50-pound tamper having a face 10 inches square. Concrete pavement must never be laid over an old macadam road bed until the latter has been thoroughly broken up and compacted into a homogeneous subgrade by rolling, thus forming a uniform and unshifting foundation for the concrete. If this be neglected, cracks in the concrete may result from irregularities in the subgrade. Wherever a fill is necessary, special care must be taken to have the earth deposited in thoroughly-compacted layers not exceeding one foot in thickness.

98. Drainage.—To prevent the accumulation of water in the earth immediately beneath the pavement, drainage should be provided. Ordinarily surface water can be handled through catch basins in connection with the storm-water sewer system, as the pavement joins the curb (being separated by expansion joint) and forms a gutter for easy disposal of rain water. Where the ground is saturated with moisture at certain seasons of the year, tile drains should be provided.

99. Thickness.—In one-course pavement the thickness of concrete at the edges should be at least 6 inches; in two-course pavement the thickness of the concrete base at the edges should be at least 5 inches and the minimum thickness of the wearing course 2 inches. In either one or two-course pavement the crown should not exceed one per cent of the width.

100. Comparison of One and Two-course Pavement.—One-course concrete pavements have been so successful and so free from the need of repairs that they are generally used where it is possible to obtain suitable material for the aggregate at reasonable cost. In some places the material desired for aggregate must be shipped from a considerable distance, and to reduce this expense local materials are used in the base, while the higher-priced aggregate is incorporated in the wearing course only. This is especially true where the expectation of excessive wear demands the use of granite aggregate on account of its high resistance to abrasion. The labor involved is somewhat greater than in laying a one-course pavement, except on wide streets using reinforcement, where labor would be the same in either case on account of the necessity for placing reinforcement in the concrete.

101. Aggregate.—Too much stress can not be laid upon the importance of carefully selecting aggregates. Neither bank-run gravel nor crusher-run stone should be used without screening and proper proportioning. Fine aggregate should consist of sand or screenings from clean, hard, durable crushed rock or gravel, consisting of quartzite grains or other equally hard material graded from fine to coarse, with coarse particles predominating, and passing when dry a screen having $\frac{1}{4}$-inch openings. Sand should be clean, hard, free from dust, loam, vegetable or other deleterious matter. Not more than 20 per cent should pass a sieve having 50 meshes per linear inch, and not more than 5 per cent should pass a sieve having 100 meshes per linear inch. Fine aggregate containing more than 3 per cent of silt such as clay or loam should be washed before using.

Coarse aggregate should consist of clean, hard, durable gravel or crushed rock, meeting the requirements of standard tests for hardness; graded in size; free from dust, loam, vegetable or other deleterious matter; and should contain no soft, flat or elongated particles. Coarse aggregate should be of such size that it will pass a screen having 1½-inch openings, and be retained on a screen having ¼-inch openings. Aggregate for the wearing course should consist of a mixture of two parts of the material specified under "fine aggregate" and three parts of clean, hard, durable gravel or crushed rock meeting the requirements of standard abrasion tests, free from dust, soft particles, loam, vegetable or other deleterious matter, passing when dry a screen having ½-inch openings and being retained on a screen having ¼-inch openings.

102. Proportioning.—For one-course pavement the concrete should be mixed in proportions of 1 sack of Portland cement, 2 cubic feet of fine aggregate, and 5 cubic feet of coarse aggregate. For the base of two-course pavement proportions should be 1:2½:4. Mortar for the wearing course should be mixed in the proportion of 1 sack of Portland cement, to 2 cubic feet of wearing course aggregate.

103. Mixing.—Materials should be mixed with sufficient clean water, free from alkali, acid, or oil, to form a "quaky" mixture, which when deposited will by its own weight settle to a flattened mass but will not be wet enough to cause a separation between the coarse aggregate and the mortar. Materials should be mixed to the desired consistency in a batch mixer and mixing should continue for at least 45 seconds after all materials, including water, have been deposited in the drum. The speed of the drum should not exceed 20 revolutions per minute for a batch using 1 bag of cement, and should be slightly slower for larger batches. If revolved too rapidly, materials will cling to the drum by centrifugal force and mixing will not be thorough.

104. Placing.—The concrete mixture should be placed in forms of steel, or of 2-inch lumber free from warp and protected upon the edges by 2-inch angle iron. Forms should be of a height equal to the thickness of the pavement at the edges. No dried concrete should be left sticking to the forms. They should be carefully cleaned each time they are used. Forms for one-course pavement are usually 6 inches high, as this type of pavement should be at least 6 inches thick at the edges, with a crown equal to 1/100 of the width. As pavement is laid from curb to curb on city streets, forms are usually unnecessary in constructing city pavements.

Prior to placing concrete, the previously compacted subgrade should be brought to an even surface and thoroughly wet. Concrete should be deposited rapidly in successive batches to the required depth and for the entire width of the pavement. The operation of depositing should be continuous between transverse joints without the use of any intermediate forms. For two-course pavement the concrete base should be brought to a comparatively even surface at a distance below the established grade of the pavement corresponding to the thickness of the wearing course, and the wearing course should be placed immediately after mixing, so that less than 45 minutes will elapse between the time of mixing concrete for the base and placing the wearing course.

105. Reinforcement.—Concrete pavement 20 feet or more in width should be reinforced. The cross-sectional area of the reinforcing metal running parallel to the center line of the pavement should amount to at least 0.038 square inch per foot of pavement width, and the cross-sectional area of reinforcing metal perpendicular to the center line of the pavement should amount to at least 0.049 square inch per foot of pavement length. Reinforcing metal should not be placed less than 2 inches from the finished surface of the pavement and should extend to within 2 inches of all joints, but should not cross them. Adjoining widths of metal fabric should be lapped not less than 4 inches.

In two-course pavement the reinforcing metal should be placed between base and wearing course. An expansion joint of at least $\frac{1}{4}$ inch should always be left between the edge of the pavement and the curb. Longitudinal joints in pavements have been found unsatisfactory and are no longer used. Transverse joints are essential; should extend entirely through the pavement; are usually spaced 35 feet apart; vary in width from $\frac{1}{4}$ to $\frac{3}{8}$ inch; should be filled with tarred felt, bitumen, or other material which will not lose elasticity under changes in temperature, and should be protected by metal plates conforming exactly to the finished surface of the pavement and securely anchored in the concrete.

106. Finishing.—The surface should be struck off by means of a template (Fig. 36) conforming to the crown and moved longitudinally, or by a strike-board moved crosswise

Fig. 36.—Near view of curved strike board for giving the crown to the pavement, showing also concrete bucket, mixer, boom, and steel expansion joint in place.

of the pavement and resting upon cross forms conforming to the crown. A suitable bridge should be used to prevent workmen walking on freshly-laid concrete while finishing, which should be done with a wood float.

107. Protection.—As soon as the concrete is sufficiently hard to prevent pitting, the pavement surface should be sprayed with water and should be kept wet until an earth covering is placed. As soon as can be done without damaging the concrete, the surface of the pavement should be covered with not less than 2 inches of earth, or other material that will afford equally-good protection, and this covering should be kept moist for at least ten days. When deemed necessary, freshly-laid concrete may be protected from sun, wind, rain, or frost, by a canvas covering until the earth covering can be placed. Under the most favorable conditions for hardening in hot weather the pavement should be closed to traffic for at least fourteen days, and in cool weather for an additional time.

108. Alley Pavement.—Concrete is rapidly becoming the standard material for paving alleys as well as streets. The essential requirements for alley pavement are that it should be smooth but not slippery and of such uniform texture that it will wear without producing ruts. Concrete is the only reasonably priced pavement meeting these requirements. Examples of concrete alley pavement in successful use for many years are easily found. Richmond, Indiana, has 30,000 square yards, some of which has been in service seventeen years; Dayton, Ohio, has 43,000 square yards, and many other cities have for several years used concrete exclusively for paving alleys.

Alley pavements are not essentially different from street pavements, except in the method of disposing of surface water. Inasmuch as alley pavements closely adjoin abutting property, drainage can not be had at the sides of the alley and must be obtained centrally. Consequently the surface of the alley is dished instead of crowned. Longitudinal drainage in alleys is provided for by sloping the pavement from the center of the block down to the street drains at the ends of the block.

Alley pavements are usually 6 inches thick in residence districts and 8 inches in business sections. For widths up to 20 feet, reinforcing is not generally specified. Alley pavements are seldom over 16 feet wide, but when laid on a fill or subjected to heavy traffic, the use of wire fabric or steel reinforcing rods of sufficient size is generally thought advisable.

Pavement may be either of one or two-course type. Where the aggregate obtainable in the vicinity is not suited for the wearing surface and other material must be shipped in, the two-course pavement is probably advisable because cheaper, as in this way the more expensive materials may be used in the wearing course only. The marked success of one-course alley pavement indicates that wherever suitable materials are available this type is to be recommended.

For alleys a dished subgrade and uniform thickness of concrete is advisable, as there would be no benefit derived from increasing the thickness of concrete at the edges.

Methods, of proportioning, mixing, placing, and finishing alley pavements are the same as described in connection with street pavements, templates being made to conform to the inverted crown or dished surface of the alley.

Alleys are usually laid in 25-foot sections leaving expansion joints between sections. Joints are filled and protected as in street pavements. The practice of corrugating the concrete in alleys should be discouraged, as it results in unnecessary noise and excessive wear. Finishing with wood float will afford sufficient foothold.

109. Highway Pavement.—Construction of concrete highways differs but little from the construction of street and alley concrete pavements. A concrete highway is not built the entire width of the road, being usually a strip of concrete varying in width from 10 to 18 feet and intended to bear the burden of highway traffic while shoulders of gravel, broken stone, or other inexpensive material on each side provide for passing vehicles.

Suitable drainage ordinarily may be provided by ditches, but provisions for drainage will depend upon local conditions. If underground water is present tile drains must be laid at a depth of three feet on each side of the roadway, or on one side with cross drains from the other side.

As concrete highways seldom exceed 20 feet in width, a flat subgrade is recommended, and whatever crown is desired is made in the concrete. While concrete highways have been laid flat, a slight crown not exceeding $1/100$ of the width is considered desirable, as it prevents the formation of ice upon the surface in winter. Expansion joints on country highways should be provided at intervals of from 25 to 50 feet. Joints should be protected by metal plates and filled with a $\frac{3}{8}$-inch layer of prepared felt.

In other respects the construction of concrete highways requires the same practice outlined for one-course concrete pavements. Two-course construction is not generally used for concrete highways.

Before the introduction of concrete as a paving material there appeared to be no economical type of permanent paving material suited to country highways. All other paving materials except macadam were debarred from extensive use because of their high cost. Macadam required such constant repairs that its upkeep was prohibitive. After concrete had been successfully used in paving streets and alleys in more than fifty American cities; had demonstrated its suitability as a paving material under all climatic conditions; had shown its first cost to be little more than macadam and its maintenance cost to be negligible, concrete pavements extended from city streets to suburban roads, and then branched out into the great network of country highways. Very interesting facts are available concerning the later developments of concrete road building.

Examples.—Near Coshocton, Ohio, a 10-foot concrete road has replaced a block stone road that gave way under heavy floods and travel. In the same locality an 18-foot strip, being the full width of the road, replaced a limestone macadam road whose life was only one year, due to heavy traffic. These roads were built of 1:2:4 mixture using river gravel and sand for aggregate. The concrete is 5 inches thick with one-inch wearing surface, the latter being mixed in the proportion of 1:2.

At Carlinville, Illinois, twenty-five property owners decided to have a good road. They organized a committee, hired an engineer, and built three-quarters of a mile of concrete roadway 18 feet wide, at a cost of $5,000. The concrete was mixed in proportions of 1:2:3½. The pavement is one-course, 6 inches thick, finished with wood float, and has expansion joints every 50 feet.

After a careful study of concrete roads in Fond du Lac, Plymouth, Sheboygan, Port Washington, Milwaukee, and Sioux City, Cook County (Chicago) has built 4,000 feet of 16-foot concrete highway between Evanston and Niles Center, on foundation that is boggy for one-third of the distance. Hence, the success of concrete on this roadway demonstrates its adaptability under unfavorable conditions. Concrete is 6 inches thick at the sides and 8 inches at the crown; the subgrade was rolled flat before placing the concrete; the aggregate was washed sand and gravel; concrete was mixed in proportions of 1:2:3, and the cost including grading was $1.59 per square yard. Where the subgrade was

BEFORE

AFTER

FIG. 37.—The possibilities of concrete for reclaiming lost highways.

boggy, consisting of black, sticky soil underlaid by blue clay, the ditches were cut very deep to insure perfect drainage. The road was protected from traffic for two weeks during warm weather and three weeks during cold weather.

The Lincoln Highway is the most stupendous highway undertaking of modern times. The vision of a concrete road 3,400 miles long may yet be realized. A portion of the Lincoln Highway has already been paved with concrete in Illinois, and arrangements have been completed for using concrete paving upon other portions passing through Ohio, Indiana, Iowa, and Nebraska.

Rapid progress is being made in concreting 24 miles of the famous National Pike, between Zanesville and Hebron, Ohio. The work is being done under the supervision of the United States Office of Public Roads and the Ohio State Highway Department. This section of road pavement is 16 feet wide with an average thickness of 7 inches.

Ohio is now using concrete pavement in 29 counties; Sioux City, Iowa, has 30 miles in satisfactory use; Milwaukee County, Wisconsin, more than 50 miles; Wayne County, Michigan, more than 100 miles; Los Angeles County, more than 250 miles, while the state of California has more than 800 miles.

The possibilities of concrete for reclaiming lost highways are shown in Fig. 37.

Examination Questions

44. What should be considered as of first importance in the science of road building?
45. What has been the principal road-building material used in Wayne County, Michigan?
46. What crown is required in building a concrete pavement or roadway?
47. What are the minimum thicknesses specified for one-course and two-course pavement?
48. How much water should be mixed with materials for concrete pavement?
49. Under what conditions should concrete pavement be reinforced?

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CHAPTER II

PROPORTIONING

3. Theory of Proportioning.—In order to comprehend the importance of correctly proportioning the ingredients entering into the composition of concrete we must in the beginning obtain a correct idea of the theory of the material we propose to manufacture.

The aggregates consisting of sand and gravel or broken stone are wholly inert, until combined with Portland cement. Consequently it is of prime importance that every piece of coarse aggregate be thoroughly surrounded with sand-cement mortar, and that every grain of sand be enclosed in a film of neat cement. In so far as actual practice departs from this fundamental principle, just so far will the bonding be defective.

The second important principle of concrete composition is that voids shall be eliminated by such gradation of materials that the spaces between larger pieces of the coarse aggregate will be occupied by smaller pieces, and the spaces between these will in turn be filled by sand until, in a perfectly proportioned mixture, there will remain only such voids as will be taken up by the cement solution when the concrete is finally compacted in the place of its ultimate use. The absolute elimination of voids is an ideal condition, hence it is essential to use every means in our power toward approaching the perfection suggested. The more nearly we approximate the theoretical possibility, the more successful we shall be in actual practice.

4. Object of Proportioning.—Both strength and density in finished concrete construction are dependent upon careful proportioning. A very porous concrete may under certain conditions of manufacture be stronger than a very dense concrete which is lacking in cement or in coarse aggregate. Hence, we observe work disintegrate after two or three years, and upon examining a fracture find that the concrete has no large voids but is composed of fine sand with little or no coarse aggregate. Such material may appear dense, but hardly deserves to be called concrete.

On the other hand, remarkable instances of strength developed in porous concrete may be observed where the coarse aggregate was fairly well graded and but little sand used. This practice is not recommended because the working conditions might not be identical, and a concrete possessing a large percentage of voids will not be watertight. The point is mentioned merely to emphasize the fact that coarse aggregate and cement give strength to concrete. Sand increases the density.

Impermeability, or resistance to the passage of water, is one of the most prominent characteristics of good concrete and is absolutely dependent upon the elimination of voids, which results only from correct proportioning of ingredients. A porous concrete is never watertight. Quite a number of processes for waterproofing have been suggested, some like soap and alum or the "Sylvester Process" are public property, while others are either secret formulas or process patents. Some consist of incorporating compounds in the concrete at the time of mixing, and others of applying compounds to the exterior or interior of the work after completion. If the concrete is properly proportioned, there is no reason for using any extraneous waterproofing medium.

In reinforced-concrete work a satisfactory bond between the steel and concrete can be obtained only by such careful proportioning as will insure a concrete practically free from voids. This does not mean merely slushing in water enough to fill spaces between aggregate surrounding rods or other reinforcement. Surplus water will disappear by evaporation, leaving cavities adjacent to the reinforcement, and when a failure occurs rods will be found pulled out of porous concrete which lacked the bond that saves structures.

5. Methods of Proportioning.—The following methods of proportioning concrete are in general use

1. Arbitrary selection of proportions.
2. Void determination.
3. Proportioning by trial mixtures.

Proportioning by Arbitrary Selection.—As many users of concrete do not wish to take the trouble to test their own materials, it is customary for them to use the proportions which have been found to produce satisfactory results under average conditions. These are one part of cement, two and one-half parts of sand, and four parts of coarse aggregate (expressed 1:2½:4) for most classes of construction. In the manufacture of products large enough to use aggregate exceeding one inch in greatest dimension, the proportion of coarse aggregate may be increased accordingly. Conversely, where a fine texture is desired for ornamental purposes, the proportion of cement must be increased reaching its maximum in 1:1½ trowelled surfaces. The following table gives the proportions recommended for various classes of work:

Concrete

A 1:2:3 mixture for:

- One course concrete highway, street and barnyard pavements.
- One course floors and walks.
- Roofs.
- Fence Posts and for sills and lintels without mortar surface.
- Water troughs and tanks.

A 1:2:4 mixture for:

- Reinforced concrete floors, beams and columns, large engine foundations.
- Work subject to vibration.

A 1:2½:4 mixture for:

- Building walls above foundation.
- Silo walls.
- Base of two course street and highway pavements.
- Backing of concrete block and similar cement products.

A 1:3:5 mixture for:

- Basement walls and foundations.
- Small engine foundations.
- Base of sidewalks and two course floors.
- Mass concrete footings, etc.

Mortar

1:1½ mixture for:

- Wearing course of two course floors.

1:2 mixture for:

- Scratch coat of exterior plaster.
- Facing blocks and similar cement products.
- Wearing course of two-course walks, street and highway pavements.

$1:2\frac{1}{2}$ mixture for:

Finish coat of exterior plaster.
Fence posts, when coarse aggregate is not used.

1:3 mixture for:

Concrete blocks when coarse aggregate is not used.
Cement drain tile, when coarse aggregate is not used.

When proportions of the ingredients of a concrete are specified, the specifications should state whether the cement shall be measured loose or as packed in bags and barrels. The reason for this is clear when it is considered that loose cement occupies about 30 per cent more volume than packed cement. The usual method is to specify the barrel of packed cement as the unit, and to assign it some definite volume—the sand and stone to be measured loose.

A barrel of Portland cement weighs 376 lb., not including the barrel, and a bag of Portland cement weighs 94 lb.; in other words, there are four bags to a barrel. For convenience the bag of cement is usually assumed as one cubic foot in proportioning but is actually somewhat less, depending on the brand. When a barrel is assumed to contain 3.8 cu. ft., as is sometimes done, then 100 lb. of cement can be considered as one cubic foot.

It should be stated here that the common rule of thumb method of proportioning concrete may cause wide discrepancies because of the variation in the character of the ingredients. In fact, arbitrary selection should never be permitted except where the work is not expensive or important enough to warrant special proportioning of the materials and grading of the aggregates.

If arbitrary proportioning is decided upon, the best method to follow is to proportion the cement to sand by judgment in accordance with the character of the construction, to adopt (as a trial) twice as much stone as sand by volume, and then to vary this proportion using as much of the coarse aggregate as possible without producing noticeable voids or stone pockets in the concrete. In cases where the coarse material contains a great many small particles, the proportion of sand should be tried at somewhat less than one-half the volume of stone.

Experience in the handling of concrete enables one to judge readily whether the mortar is deficient or not. With too little sand, stone pockets are apt to occur on the surfaces, and it is difficult to fill all the voids in the stone; with too much sand, a harsh working of the concrete will be noticed or an excess of mortar will rise to the top when placing.

Proportioning by Void Determination.—There are four distinct methods of proportioning concrete by the determination of voids:

(a) Finding the voids in the stone and in the sand, and then proportioning the materials so that the volume of sand is equivalent to the volume of voids in the stone and so that the volume of cement is slightly in excess of the voids in the sand. (The excess of cement is provided on account of inaccuracies in the void method of porportioning.)

(b) Finding the voids in the stone, and, after selecting the proportions of cement to sand by test or by judgment, proportioning the mortar to the stone so that the volume of mortar is slightly in excess of the voids in the stone.

(c) Mixing the sand and stone and providing such a proportion of cement that the paste will slightly more than fill the voids in the mixed aggregate.

(d) Making trial mixtures of dry materials in different proportions to determine the mixture giving the smallest percentage of voids, and then adding an arbitrary percentage of cement, or one based on the voids in the mixed aggregate.

Proportioning by the determination of voids is little (if any) better than the proportioning by arbitrary assignment. In the first place, the percentage of voids in sand is greatly affected by even a small percentage of moisture. When sand is moistened, a film of water coats each particle of sand and separates it by surface tension from the grains surrounding it. Fine sand, having a larger number of grains, and consequently, more surface area, is more increased in bulk by the addition of water than coarse sand. Again, the volume of water required in mixing actually occupies space in the resulting concrete and not only every cement but also every sand has a different and definite percentage of water necessary to bring it to what may be called normal consistency. Voids in absolutely dry sand are certainly no criterion of its qualities for concrete, while a moist sand will give different results on different days.

Inaccuracy in proportioning by void determination is also due in part to the difference in the compactness of the materials under varied methods of handling, and to the fact that many grains of the sand are too coarse to enter the voids of the stone and consequently thrust apart the particles of the large aggregate. Many of the voids in the sand are also too small for the grains of cement to fit into them without expanding the volume.

Percentage of voids is usually determined by finding the specific gravity of the solid particles, weighing a known

Fig. 9.—The impossibility of obtaining proper and uniform proportion from this average gravel bank is self evident.

volume of the aggregate and computing therefrom the percentage of voids. The voids in sand will average about 33 per cent, while in stone or gravel the open space averages in the neighborhood of 45 per cent.

Proportioning by Trial Mixtures.—The fact that the densest concrete is the strongest and most impermeable makes possible a convenient and accurate method of proportioning concrete and of determining the relative value of different aggregates. Mr. William B. Fuller describes the method as follows:

"Procure a piece or steel pipe 8 to 12 in. in diameter and a foot long and close off one end; also obtain an accurate weighing scale. Weigh out any proportions selected at random, of cement, sand, and stone, and of such quantity as will fill the pipe about three-quarters full, and mix thoroughly with water on an impervious platform, such as a sheet of iron; then, standing the pipe on end, put all the concrete in the pipe, tamping it thoroughly, and when all is in, measure and record the depth of the concrete in the pipe. Now throw this concrete away, clean the pipe and tools and make up another batch with the total weight of cement, sand, and stone the same as before but with the proportions of the sand to the stone slightly different. Mix and place as before and measure and record the depth in the pipe, and if the depth in the pipe is less and the concrete still looks nice and works well, this is a better mixture than the first. Continue trying in this way until the proportion has been found which will give the least depth in the pipe. This simply shows that the same amount of materials is being compacted into a smaller space and that, consequently, the concrete is more dense. Of course, exactly similar materials must be used as are to be used on the work, and after having in this way decided on the proportions to be used on the work it is desirable to make such trials several times while the work is in progress, to be sure there is no great change in materials, or, if there is any change, to determine the corresponding change in the proportions.

"The above-described method of obtaining proportions does not take very much time, is not difficult, and a little trouble taken in this way will often be productive of very important results over the guess method of deciding proportions so universally prevalent.

"A person interested in this method of proportioning will find on trial that other sands and stones available in the vicinity will give other depths in the pipe, and it is probable that by looking around and obtaining the best available materials the strength of the concrete obtainable will be very materially increased."

6. Sizing Materials.—Unless sand and gravel are purchased separately, it will be necessary to separate them by screening to arbitrary sizes before proportioning. If, for instance, it is proposed to use bank gravel varying in size from fine sand up to small boulders two screens should be used. The first should reject everything exceeding the maximum size of aggregate suitable for the work, this varying from ¾ inch, for fence posts and block, up to 2 inches for foundations and other work of large cross section. The general rule for walls is that the largest size of aggregate shall not exceed, in its greatest diameter, one-half the thickness of the wall. The second screen should in all cases be of $\frac{1}{4}$-inch mesh, the particles retained upon it to be regarded as coarse aggregate, and those passing it as fine aggregate, or sand.

The following is taken from a paper on *The Selection and Proportioning of Concrete Aggregates* by Mr. C. K. Arp of Chicago, presented at the Conference on Permanent and Sanitary Farm Improvements in August, 1913:

"Many are of the opinion that when a 1:2:4 mixture is required, it is possible to obtain this by taking one part

FIG. 10.—In some parts of the gravel bank the material consists almost entirely of coarse particles.

of cement and 6 parts of mixed aggregate or bank-run gravel. As previously stated, bank-run gravel does not occur in the proper proportions of fine and coarse material, but assuming that it did, it can very easily be demonstrated that the 1:2:4 mixture is much richer in cement than the 1:6.

"Take, for example, 2 cubic feet of sand to which we add 1 cubic foot or one sack of cement. When mixed together the cement is practically contained in the voids or open spaces in the sand, so that the resulting mortar is very little over 2 cubic feet in volume. If, now, we add this mortar, which is the 1:2 portion of our 1:2:4 mixture, to 4 cubic feet of screened gravel or stone, the same condition is repeated and the mortar is practically contained in the voids in the stone. As a result the volume of mixed concrete is little more than 4 cubic feet.

"Likewise in adding one sack of cement to 6 cubic feet of bank-run gravel, the cement is contained in the larger amount of open space between the particles, the concrete resulting being 6 cubic feet, the volume of the bank-run gravel. Thus, it should be clear that in one case we have 4 cubic feet of concrete with one sack of cement, and in

Fig. 11.—A slanting screen can be made to separate the sand from the coarse material in bank-run gravel, making possible a great improvement in the quality of the concrete produced.

the other 6 cubic feet of concrete with a like amount of cement, which means that the latter is a leaner and weaker mixture.

"To make a bad condition worse, bank-run gravel invariably contains an excess of sand, which assists further in weakening the concrete. Therefore, it is always better to separate the sand and gravel by screening and afterward remixing the two in the proper proportions.

"For minimum voids and the best concrete, the size of the fine aggregate should grade from $\frac{1}{4}$ inch in the largest dimensions, down to the finest, with the coarser particles predominating, and in no case should fine aggregate be used, of which more than five per cent passes through a sieve having 100 meshes per linear inch."

7. Amount of Water.—The consistency will depend upon the use for which the concrete is intended and upon the process of manufacture necessarily associated therewith.

Three consistencies or mixtures, determined by the amount of water used, are generally called the dry, the quaky, and the wet. The dry mixture is of the consistency of damp earth, and is used where the concrete is tamped into place, being principally useful in steel molds for making products requiring no reinforcement, such as brick, block, and ornamental vases.

The quaky mixture is so named because it is wet enough to quake or shake when tamped. It is used in all molded products requiring reinforcement, such as fence posts, lamp posts, telegraph and telephone poles, drain tile, sewer pipe, ash pit rings and the like; also in engine foundations and the footings of buildings.

The wet mixture contains sufficient water to permit of its flowing from a shovel or wheelbarrow, but not enough to cause a separation of the particles. It is used in building reinforced-concrete structures, such as silos, barns, dwellings and other buildings where the concrete is allowed to remain undisturbed in the forms for several weeks.

CHAPTER III

MIXING

8. Fundamental Principle.—The importance of thoroughly and carefully mixing the ingredients used in the manufacture of concrete is secondary only to the proportioning, because the mixing can not be done until after the proportioning has been accomplished. It is secondary in time but equal in importance.

As stated earlier in this assignment, an essential feature of concrete construction is the coating of every grain of sand with a film of neat cement and the coating of every piece of coarse aggregate with sand-cement mortar. This is the fundamental principle of all concrete construction; an earnest effort to accomplish this result will insure success.

Assuming that proper proportions have been determined, the result so carefully sought can be attained only by thorough and intelligent mixing.

9. Shovel Mixing.—Let us first consider the rather difficult problem of securing satisfactory results where the volume of work does not warrant the installation of a mixing machine.

The first requirement will be a water-tight platform large enough for two men to shovel conveniently from either end as large a batch of concrete as can be used within thirty minutes after water has been added to it. Time is essential, and if on account of meal time, or any emergency, a portion of a batch lies until the cement has become partially hardened, throw it away rather than jeopardize the work.

As proportioning is usually done by volume, one cubic foot is a convenient unit, as it allows full sacks of cement to be used. The required amount of sand should first be spread upon the mixing platform, after which the cement should be spread in a layer on the sand. Two men, using square pointed shovels, will then turn the sand and cement over two or more times until the streaks of brown and gray have merged into a uniform color throughout the mass. The coarse aggregate is then shoveled on and the mixing continued, water being added during the first turning after adding coarse aggregate. Water should be added gently, as from a hose nozzle or the spout of a watering pot, in order to prevent washing out the cement. Turning should continue until the mortar is of uniform consistency throughout, which will usually require at least three turnings after adding water.

Mixing in the above manner will give satisfactory results, but the labor involved is considerable, and on this account it is too common for those attempting it to slight the work and use the concrete in an imperfectly mixed condition.

10. Machine Mixing.—Mixers have been brought to a high state of efficiency and today there are many on the market designed to produce the best results at minimum cost of labor and power. While it is beyond the scope of this assignment to discuss mixers, we may in passing mention one or two of the principles which will assist the concrete manufacturer in making a selection suited to his needs. The batch mixers, whether cubes, cylinders or truncated cones, allow the material to be introduced in any order desired, provided only that each separate batch contains the proper relative proportions of ingredients. After the batch has been placed in the mixer, it is revolved for a specified time, or a definite number of revolutions until either by the shape of the drum itself or by means of deflectors therein, the cement, sand and coarse aggregate have been thoroughly mixed. Most batch mixers are equipped with a small tank from which a pipe leads into the mixer, and when the materials have been sufficiently mixed in a dry state, water is sprayed on them while the revolutions of the mixer continue.

The continuous mixer consists mainly of a number of hoppers for the several materials, placed over one end of a semi-circular trough containing blades or shovels fixed to a rotating shaft. The motive power is generally supplied by a gasoline engine or an electric motor. The dry materials are fed automatically from the hoppers into the trough, mixed and carried along by the blades to the discharge end, water being added; meanwhile the concrete is discharged continuously.

The batch type of mixer is considered by the majority of engineers to give the best results because the measuring of the materials can be positively regulated; whereas with the continuous mixer variations in the amount of moisture in the sand or fluffiness of the cement will cause a variation in the relative proportions of these materials in the mixture. On this account, engineers are inclined to favor the batch mixer.

Lists of manufacturers of both batch and continuous mixers will be found in the columns of current concrete periodicals.

CHAPTER IV

PLACING

11. Final Problem.—But, when all is said and done; when we have selected the best materials, have ascertained the proper proportions of each and the correct amount of water for the consistency required to serve our particular purpose; when by shovel or machine we have combined the different materials required to make concrete, we have produced a mass of material which must forthwith be honestly and intelligently deposited, compacted, and made to take some one of the thousand and one shapes which concrete assumes to serve humanity by increasing the efficiency of man.

This, then is our problem, the placing of the concrete, and we shall find three distinct methods of accomplishing this result.

12. Pressure and Tamping.—Whenever a dry mixture is used in steel molds to produce such unreinforced products as ornamental vases, block or brick, concrete is placed by pressing or tamping. If pressure is applied, it will ordinarily be by means of a press simplifying the process and making it necessary only to see that the molds are adequately and evenly filled in order that the product may be uniform in density. If, however, tamping is the method employed, considerable supervision will be found necessary as the quality of the product may vary considerably unless the tamping is uniformly performed. It is particularly necessary that the mold be tamped while filling, not filled and tamped afterward. The latter method will not only fail to fill the lower corners but will make one-half of the molded product much denser than the other. If tamping is well done by one man (or two if the mold is large) while the mold is being filled by another, there is no reason why the product should not be perfectly satisfactory and as uniform as though made under mechanical or hydraulic pressure. To secure more uniform density and effect a saving of labor, power tampers are used, the multiple tampers being especially serviceable in making block and brick.

13. Agitation.—Neither tamping nor pressure will be of service in the case of those products requiring the introduction of reinforcement, such as tile, pipe, poles and posts. In the manufacture of these and similar products, the steel (in whatever form required for reinforcing) is introduced at the proper place in the mold while it is being filled with a quaky mixture of concrete. The concrete is compacted, forced into corners and around or through the reinforcement, by vigorously stirring the mixture and jarring the mold.

14. Depositing Wet Concrete.—Placing concrete for reinforced-concrete structures, including silos and all sorts of buildings, involves work on a scale warranting the installation of special apparatus to save both time and labor in transporting the concrete from the mixer to the place of use. Elevators, dump cars, and chutes are ordinarily used in the construction of reinforced-concrete buildings. In constructing silos, it is necessary to provide a center hoisting device with derrick and an automatic dumping bucket.

The concrete is poured into forms in which reinforcement has previously been placed. It is then necessary to spade it back from the forms in order to prevent large pieces of aggregate from retaining surface positions when the forms are removed. The larger pieces of aggregate should, as far as possible, be forced away both from the reinforcement and the forms so that they may occupy an intermediate position. Though the subject of "Forms" is treated in another assignment, a word of caution relative to their removal may not be amiss at this time. While no definite rule can be given to fit all local conditions and variations of structure, humidity and temperature, good judgment will suggest that too early removal involves danger, while reasonable delay in removing forms is a wise precaution insuring safety.

Examination Questions

8. What reason is there for using a waterproofing compound in properly proportioned concrete?
9. Wherein does the density test have its value?
10. State proper proportions for fence posts when coarse aggregate is used; when it is not.
11. What is the fundamental principle of making good concrete?
12. What type of mixer do engineers favor?
13. What is the object of spading?

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CHAPTER XVI

ESTIMATING CONCRETE (Continued)

In the preceding assignment the broad general principles that must be considered in estimating for concrete construction were presented. In this lesson specific applications of these principles will be illustrated. Having available data applying to necessary materials and labor, supplemented by the estimator's personal knowledge of conditions under which a certain piece of work must be performed, the proposition becomes one of simple arithmetic.

Data illustrating average costs for each class of work generally associated with concrete construction are given in this lesson in the simplest and most direct manner possible. In some cases, however, the data available are not precise. For example, the labor of constructing forms is estimated at from \$15 to \$35 per thousand board measure. (B. M.) In any work, figures that are used for making estimates of the cost of this part of the work depend upon at least two variable conditions, namely, the complexity of forms and the cost of carpenter labor. It is evident, therefore, that estimates on form construction can not be made so accurate as can estimates for mixing and placing concrete where the data available show how much can be mixed and placed, expressed in a unit of man-hours. Therefore the estimator should keep careful record of items that at first can not well be estimated closely, so that data may be accumulated for use on subsequent jobs.

123. Reinforcing Steel.—Generally speaking, the average contractor will need to consider only one grade of reinforcing steel. This can be obtained from any of the steel companies either direct or through local hardware or building material dealers. Without going into details concerning the physical and chemical properties of steel, it will be sufficient to say that steel varies greatly in character; that is, some is very much like wrought iron, while other varieties may be compared to cast iron, especially as regards brittleness.

This should lead the contractor to realize that not all steel is suitable for reinforcing concrete.

Regardless of whether plain or deformed bars are used, steel that meets the standard specifications for steel reinforcing bars, as laid down by the American Society for Testimg Materials, should be the kind selected. Practically all of the steel companies manufacture reinforcing steel conforming to the specifications mentioned, and this ranges in tensile strength from 55,000 to 70,000 pounds per square inch. Do not think that your local blacksmith shop can supply you out of stock with the most suitable nor most economical material for reinforcing concrete; also do not think that iron pipe or any similar material made for purposes other than for use in reinforced concrete construction, can be substituted for suitable steel manufactured specifically for concrete work.

An estimate for reinforcing steel should be increased 10 per cent over the actual amount estimated, to cover shortage resulting from cutting. This allowance should be quite ample for jobs not requiring many short lengths nor much cutting of steel.

The cost of steel is generally figured in place as follows:

Cost of............pounds steel F. O. B. siding at........................per lb................
Hauling............pounds to the job, including loading and unloading................
Net cost of............pounds of steel in place at........................per lb................
(Cost of steel in place, exclusive of profit is generally figured at from 2¾c to 3c per pound).

124. Forms.—The character of the work and the cost of lumber generally determine the kind of lumber that will be used for forms. For work where an exceptionally smooth surface on the concrete is required, as in moldings and other ornamental trim, white pine is the best lumber to use. But for ordinary work, it is too expensive, and too soft to be durable where forms are to be used repeatedly. Therefore spruce, Norway pine and southern pine are generally the most economical. Short leaf pine also makes excellent form sheathing. Where spruce can be readily obtained it is perhaps the best material for studs, joists, and posts. Hemlock is too coarse grained for sheathing and splits so easily as to be unsafe for heavy framework, while the hard woods are too expensive to work.

Form lumber should be free from shakes and rot and as free as possible from knots. Knots leave their imprint on the finished surface of the concrete and in addition will weaken the lumber.

Partly dry lumber is better than kiln dried. The latter will swell and bulge at the joints, while green lumber will shrink if not kept wet, opening cracks through which water carrying cement will leak out when the concrete is placed.

Even for rough work, lumber that is dressed at least on one side and two edges is best for form sheathing so as to make the boards fit together well; and the smooth surface will reduce the labor of removing and cleaning the forms. Lumber dressed on all sides and edges is still better. The added cost is so little that the advantages of greater convenience in handling, working up, and placing, more than compensate for the increased outlay.

Tongued-and-grooved stock is often used for sheathing, although shiplap is sometimes used. Beveled-edge stock is preferred by many because if the lumber swells the edges will slip past each other without causing a warping or bulging of the boards. Beveled-edge stuff is usually cheaper than tongued-and-grooved because there is less waste of lumber in the mill. For sheathing forms which are to be used repeatedly, the tongued-and-grooved stock holds its place better and gives a smoother surface. Boards should be uniform in thickness to prevent unevenness in the surface of the concrete.

Posts used for supporting forms must be of sufficient size, stiffness and strength to hold forms firmly in place and to prevent any sagging when the load of concrete has been placed. The following table gives the maximum safe load for wood posts of various lengths and sections. Knowing the length of post, total weight of concrete and form to be supported, and the economical number of posts, the load per post can be readily determined. It should be remembered that a corner post carries only one fourth of the load carried by a side post and that a side post carries one half the load that must be borne by an inside post.

TABLE I.

Maximum Safe Load for Wood Columns

Length in Ft.	4″	6″	8″
5	9400		
6	8800		
7	8200		
8	7500	20700	
9	6900	19800	
10	6300	18900	37700
11		17900	36400
12		17000	35200
14		15100	32700
16			30200
18			27600
20			25100

Example: Flat slab 14 feet by 17 feet 8 inches, weighing approximately 60,000 pounds, 16 posts can be spaced economically in four rows of 4. There will be 4 corner posts, 8 side posts and 4 inside posts = 16 posts.

4 corner posts carry load of 1 inside post = 1
8 side posts carry load of 4 inside posts = 4
4 inside posts carry load of 4 inside posts = 4

Number of posts of equal load 9

$$\text{Maximum load per post} = \frac{60,000}{9} = 6,666 \text{ lb.}$$

Length of post 6 feet 0 inches.

From the table we find one 4 by 4-inch post 6 feet long will carry safely a load of 8,800 lb. Since no timbers of less than 4 by 4 inches should be used, this size will be adopted.

125. Estimating Forms.—One of the most accurate methods of estimating forms is to figure the board measure (B. M.) of lumber and the hardware required, the carpenter labor required per thousand B. M. to erect, the labor required for taking down and cleaning, and the cost of transporting the lumber to and from the job. A certain percentage of the cost of form lumber should be charged to the job. What this shall be can be learned from carefully tabulated data covering a number and variety of jobs that will disclose how long forms may be used repeatedly.

The amount of skilled and common labor required to make, erect, and wreck forms naturally depends upon how complicated they are and the conditions under which men work.

With the above data calculated the following method of estimating is fairly simple:

....................B. M. used at $...............per M. B. M.......................................
Total cost of lumber $...
10 to 25 per cent of this amount charged to job...
Cost of hauling lumber to job............M. B. M. at $............per M. B. M........
Cost of hauling lumber away from job...................M. B. M. at $...............
per M. B. M.......................................
Cost of hardware (nails, bolts, spikes, etc.) on job at approximately $2 per M. B. M.................................
Cost of labor and superintendence, making erecting and taking down forms with carpenters at 40 cents per hour from $15 to $35 per M. B. M. of...M. B. M...
Total cost of forms...

Carpenter labor per M. B. M. for form work is difficult to estimate accurately because there are so many factors to be considered. A carpenter experienced on concrete form work can accomplish more than one whose experience has been confined to buildings. The experienced form carpenter bears in mind that the forms must, if possible, be designed and constructed to permit using the lumber again, therefore he does no more cutting than necessary and plans the forms so that they may be easily taken down, with least damage to lumber. Straight walls and flat floors usually require the simplest type of forms, which are often built for from $10 to $20 per M. B. M. Corners, offsets, bends and any kind of breaks or projections from the plane surface, such as in columns, beams, cornices, walls with openings, angles or other variations, increase the labor cost so that it may range from $20 to $35 per M. B. M. Forms which require that workmen risk injury to themselves when erecting high scaffolds or falsework to hold heavy loads of concrete, cost from $20 to $35 per M. B. M.

The amount of hardware used can safely be estimated at $2 per M. B. M. of lumber. With a detailed plan of the forms this item may, of course, be estimated accurately.

Form lumber varies in cost from $20 to $30 per M. B. M. for new stock. With care in taking down forms it should be possible to use lumber several times, so the longer this lumber is serviceable the lower the percentage of its original cost charged to any one job. For certain classes of work form lumber can be used more than ten times, and seldom should more than 25 per cent of the cost of lumber be charged to one job unless there is much cutting of stock lengths.

Much economy in cost forms can be realized by developing unit forms as far as possible; that is, form panels or sections which can be reset in other places without alteration. This is especially true in house wall construction, beam and slab floors and columns, or in art reliefs which can be pre-cast.

There are at present on the market several types of unit forms for various classes of construction. Among the most common are those used for silo walls, tubular arches, and box culverts.

126. Hauling Charges.—This item is made up of the charges for loading and unloading, which include actual working as well as waiting time of team with driver and the team time in travel. The contractor must keep men and teams operating so that time wasted waiting for empty wagons or by teams waiting while wagons are loaded will be reduced to a minimum.

The following data are based on the time consumed by laborers and teams in hauling materials. Rate of team travel is based on from 20 to 22 miles actual distance traveled in 10 hours on average roads having average grades and occasional bad spots. Where the haul is long and there are difficult places en route it is best to run two or more teams together.

A laborer will load loose material by shoveling from ground or car into a wagon as shown in the following table.

A team will haul a load of about two cubic yards on a good road but only about half that amount over excavated or soft ground, therefore it is necessary to employ a "snatch" team in order to haul material economically under some conditions.

TABLE II.

Materials Shoveled Working Continuously	Good working conditions and without delays.		Inexperienced workmen and delays. Conservative estimating.	
	Cu. Yd. per Hr.	Tons per Hr.	Cu. Yd. per Hr.	Tons per Hr.
From car to wagons Crushed Stone	2.2	3.3	2.0	3.0
" " " " Gravel	2.7	4.0	2.0	3.0
" " " " Sand	3.5	5.0	2.5	3.75
From ground to wagons plowed clay some chunks and stones	2.0	2.5	1.5	1.9
From ground to wagons Plowed Loam	2.5	3.0	2.0	2.5
" " " " Crushed Stone	3.0	4.5	2.0	3.0
" " " " Sand	4.0	6.0	3.0	4.5

A yard of material can hardly be loaded economically by shovel gangs in less than 6 minutes time; and since team time runs high it is often profitable to employ a loading device or extra wagons which can be run in place by a snatch team or the laboring gang.

The following is based on 6-minute loading time and volume loaded of one yard:

Slat wagons:

1. Load and dump (1 cubic yard)—8 minutes.
2. Hitch, dump and unhitch (1 cubic yard)—4 minutes.

Contractor's dump wagon.

1. Load and dump (1 cubic yard)—6 minutes.
2. Hitch, dump and unhitch (1 cubic yard)—2 minutes.

TABLE III.

A team will haul on:	Pounds	Aggregate Cubic Yards	Sacks Cement	Excavation Cubic Yards
Very poor earth road	2,000	0.67	20	.8
Poor earth road	2,500	0.835	25	1.0
Good hard road	4,000	1.33	40	1.6
Good macadam or paved road	6,000	2.00	60	2.4

Two thousand feet of travel will consume 10 minutes giving a haul length of 1,000 feet. For each 1,000 additional feet of loaded haul 10 minutes should be added to time en route.

127. Hauling Cement.—A team will haul loads itemized in the foregoing table at 10 minutes per 1,000 feet of loaded haul.

Loading near stock pile takes about $\frac{3}{4}$ minutes of labor per sack of cement or 3 minutes per barrel. Unloading under similar conditions takes the same amount of time. The time which a team is delayed while doing this is dependent on the number of laborers employed. It may therefore be profitable to have additional wagons at one or both ends of the haul so that the teams will not be delayed. The time of changing wagons twice may be considered 5 minutes. To the net cost of cement when handled in sacks there should be added a charge of 10 cents per barrel to cover handling empty sacks, shipping them back and the loss of sacks which can not be redeemed.

128. Summary hauling charge.—

Labor time in loading............yards........hours at $............per hour...............
Loss of team time waiting or changing wagons....minutes at $......per min....
Team time consumed in unloading........minutes at $............per min............
Labor time consumed in assisting unloading......minutes at $......per min......
Team time........hours en route at $........per hour...
Total expense for hauling.....................yards to job.............................
Cost per cubic yard for hauling to job..
(Superintendence and overhead to be added to total estimate.)

129. Excavating and Grading.—

1. General

Dirt or clay, macadam or gravel road surface, when loosened will swell in volume from 20 to 35 per cent and go back in fill to its original volume if compacted to the same degree as in its natural condition. Earth will shrink as much as 10 per cent of its original volume, if when transferred to another location it is compacted with roller.

2. Loosening Material

1. With Plow:
    (a) One plow, team and driver, and one helper will loosen 35 cubic yards ordinary earth, per hour.
    (b) One plow, team and driver, and one helper will loosen 15 to 20 cubic yards of dirt or clay road surface per hour.
    (c) A pick-pointed plow, four horses, two drivers, one helper will loosen 19 yards of extra tough surface, including macadam or gravel, per hour.

2. With picks:
    One man will loosen as follows per hour:
    3½ yards of average earth.
    2 yards of tough clay.
    ¾ yards of hardpan.

3. Moving Material

1. Scrapers limit haul "Drag" 200 feet; "Wheel" 500 feet.

Drag	25	ft.	haul,	1	scraper,	1	team & driver,	1	helper	move	60	yd.	per	day.
"	50	"	"	3	"	3	"	1	"	"	150	"	"	"
"	100	"	"	3	"	3	"	1	"	"	120	"	"	"
"	200	"	"	3	"	3	"	1	"	"	105	"	"	"
Wheel	200	"	"	3	"	3	"	1	"	"	120	"	"	"
"	300	"	"	3	"	3	"	1	"	"	100	"	"	"
"	400	"	"	3	"	3	"	1	"	"	80	"	"	"
"	500	"	"	3	"	3	"	1	"	"	65	"	"	"

2. Shoveling into wagons or carts (see Table II).
3. Hauling by wagons (see Table III).

130. Mixing, Placing, and Handling Concrete With Not Less Than Minimum Nor More Than Maximum Sized Gangs.—

1. Mixing by hand 0.2 yards per man per hour.
2. Stationary mixer with elevated loading platform, wheeling short distance to mixer, ⅔ cubic yards per man supplying material to mixer and operating mixer.
3. Movable mixer with mechanically hoisting loading skip, 1 to 1¼ cubic yards per hour per man supplying materials to mixer and operating mixer.
4. Following is shown the amount of "quaky" consistency concrete which has a tendency to slop over when hauled in wheelbarrows on level or average grades from mixer to the place of depositing; and also includes the labor cost of extra men necessary to place and spread or spade the concrete.

25	foot	haul	0.75	cubic	yards	per	man	per	hour
100	"	"	0.50	"	"	"	"	"	"
150	"	"	.40	"	"	"	"	"	"
200	"	"	0.33⅓	"	"	"	"	"	"
225	"	"	.30	"	"	"	"	"	"

The above are safe estimates where the crew is balanced so that no portion of it is materially delayed by any of the others.

When the mixer can be kept sufficiently close to the place where concrete is being deposited the only labor required is that necessary to spread the concrete. One man can handle up to 2.5 cubic yards per hour; two men can generally accomplish more than twice that of one man and 4 men can handle from 12 to 16 cubic yards per hour, depending on the nature of the work.

Where the concrete must be hoisted above the level of the mixer the problem is simple to solve, but it is difficult to give any general cost data because of the variation in character of plants and the many different heights to which the concrete is raised. When once chosen however, the plant, remains constant in daily operating cost, while its output is dependent upon time of operation.

For example: A one-horse operated winch is used to hoist concrete in silo work. The quantity of concrete deposited each day must be the same, as the forms must be filled once each day. As the height of hoist increases, the time consumed in raising the bucket of concrete increases; the horse must work more hours to raise the same amount of concrete and the time of the gang is lengthened accordingly. When using the engine hoist attached to the mixer the same results are obtained.

Where the quantity of concrete to be deposited in a given period may be variable, the cost will vary unless the size of the gang is kept adjusted to working conditions.

Several types of the ordinary elevator hoists are available, and their output may be estimated by dividing ¼ the loaded speed in feet per minute into the height to which operating. There is also an endless chain hoist with lugs which catch the barrow or wheel carts, carry them to the required height, automatically set them off and return the empties in the same manner. With this equipment the output may be maintained constant by adjusting the number of carts or barrows; then the cost of raising concrete would be the cost of operating the hoist together with accessories.

Concrete is sometimes delivered by gravity spout or chute, but here the hoist problem is the same, and the spout substitutes the conveying of concrete by barrows or carts from the elevator to place where deposited.

For general estimating the following cost of concrete work complete, may be used. These figures include forms, profit and all other necessary items.

Concrete in large masses $4 to $6 per cubic yard where few forms enclose a large quantity of concrete. For example: Engine foundations, pavement foundations, building foundations, bridge abutments and walls of 2 or more feet thickness and of medium height.

Plain concrete walls from 8 to 16 inches thick, and other plain concrete construction requiring simple form work and some steel reinforcement for temperature stresses $6 to $8 per cubic yard.

The same class of work but more complicated, up to $12.

Reinforced concrete work including bridge floors, building construction, etc., $12 to $20, with a general average figure of $15.

*Concrete sidewalks $7 to $9 per cubic yard.

*Concrete street pavements $7.50 to $9.50 per cubic yard.

131. Surface Treatment of Concrete.—There being practically no limit to the variation possible in the treatment of concrete surfaces, naturally the cost must often resolve itself into the known items such as materials required, scaffolding, and the unknown quantity of labor, which must be conservatively estimated from the contractor's knowledge of the surface area the men available can treat in a given time. Hence the contractor must have personal knowledge of the ability of the men who will actually do the work, or feel certain that he can teach men to do it at an estimated rate.

The following table gives the quantities of materials required for Portland cement exterior plastering of varying thicknesses:

---

*Note: For his own information the contractor must figure the *volume* of concrete. As pavement specifications may vary in stating the thickness required, the contractor will then reduce his cubic-yard cost to a square-yard basis, as paving costs are usually expressed in this way.

TABLE IV.

NUMBER OF SQUARE FEET OF WALL SURFACE COVERED PER SACK OF CEMENT, FOR DIFFERENT PROPORTIONS AND VARYING THICKNESS OF PLASTERING.

Proportions of Mixture	Materials			Total Thickness of Plaster				
	Sacks Cement	Cu. Ft. Sand	Bushels Hair*	½″	¾″	1″	1¼″	1½″
				Sq. Ft. Covered	Sq. Ft. Covered	Sq. Ft. Covered	Sq. Ft. Covered	Sq. Ft. Covered
1:1	1	1	⅛	33.0	22.0	16.5	13.2	11.0
1:1½	1	1½	⅛	42.0	28.0	21.0	16.0	14.0
1:2	1	2	⅛	50.4	33.6	25.2	20.1	16.8
1:2½	1	2½	⅛	59.4	39.6	29.7	23.7	19.8
1:3	1	3	⅛	67.8	45.2	33.9	27.1	21.6

*Used in scratch coat only.

These figures are based on average conditions and may vary 10 per cent either way, according to the quality of the sand used. No allowance is made for waste.

After having decided upon the thickness of the wall plaster and the mixture to be used, it is easy to determine the total materials required for covering a given wall surface, since the table shows the number of square feet of surface covered by the mortar resulting from one sack of cement. Waste can be reduced by placing a plank on the ground at the base of the wall to catch plaster that falls. Such plaster should never be used after it has once begun to harden and therefore should not be allowed to accumulate but should be gathered up promptly and remixed with the mortar already prepared. Cement plaster should not be mixed in batches larger than are needed for immediate use, otherwise some of the mortar may begin to harden before it can be used and must be thrown away.

Cement stucco work generally costs from $1.50 to $1.75 per square yard including building paper and wood or metal lath, the metal lath costing a little more than the wood. The two-coat smooth work often costs less than $1.50. When granite or marble chips are used in the rough exposed dry or other dash, the extra cost of such materials may raise the price to $1.75 or slightly more.

Uniform surface coloring of concrete or mortars is obtained by mixing certain coloring material with the cement before adding to the aggregate. The following table gives helpful estimating data.

TABLE V.

COLORED MORTARS

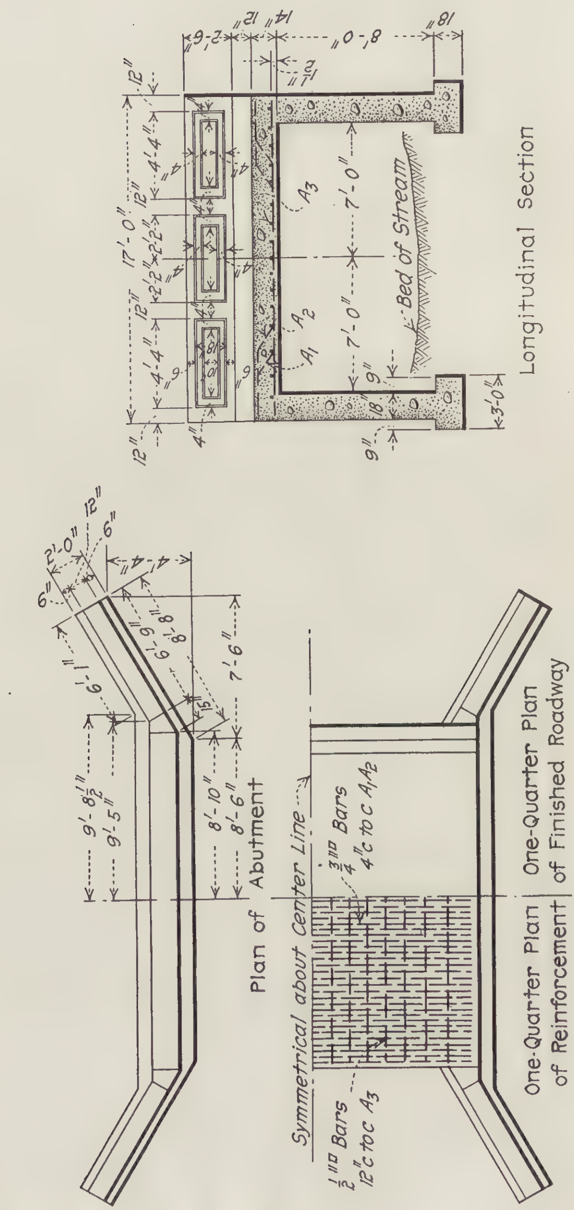
Colors given to Portland Cement Mortars Containing Two Parts River Sand to One Cement.

Dry Material Used	Weight of Dry Coloring Matter to 100 lb. Cement.			
	½ Pound	1 Pound	2 Pounds	4 Pounds
Lamp Black	Light Slate	Light Gray	Blue Gray	Dark Blue Slate
Prussian Blue	Light Green Slate	Light Blue Slate	Blue Slate	Bright Blue Slate
Ultra Marine Blue	....	Light Blue Slate	Blue Slate	Bright Blue Slate
Yellow Ochre	Light Green	....	....	Light Buff
Burnt Umber	Light Pinkish Slate	Pinkish Slate	Dull Lavender Pink	Chocolate
Venetian Red	Slate, Pink Tinge	Bright Pinkish Slate	Light Dull Pink	Dull Pink
Chattanooga Iron Ore	Light Pinkish Slate	Dull Pink	Light Terra Cotta	Light Brick Red
Red Iron Ore	Pinkish Slate	Dull Pink	Terra Cotta	Light Brick Red

In the cost of the washed exposed aggregate surface, that is, where the form face is plastered with chips or colored pebbles backed by the regular wall concrete, and after the forms are removed, the surface film of cement is washed by water and brushed or washed with a weak solution of acid, the extra cost generally runs from 5 to 10 cents per square foot of surface.

Concrete wall surfaces are treated by one coat of cement mortar, smooth or dash finish, at a cost of approximately 5 cents per square foot. Concrete surfaces are frequently tooled to reveal the aggregate.

The tooth-axed surface is probably the most widely known. This work is done by lightly chipping with a tooth axe and thus breaking away the surface skin of the concrete. The work is generally done in panels or to produce designs with borders or certain areas left smooth. The smooth surfaces are rubbed with cement grout and a sand brick and pointed up. The work generally is contracted for at from 6 to 7 cents per square foot of exposed area of the building with the addition of all areas to be treated at angles to the surface. Stone cutters are preferable for this work, and one man will


Longitudinal Section
Bed of Stream
Plan of Abutment
Symmetrical about Center Line
$\frac{3}{4}$" □ Bars 4"c to c A_1A_2
$\frac{1}{2}$" □ Bars 12"c to c A_3
One-Quarter Plan of Reinforcement
One-Quarter Plan of Finished Roadway

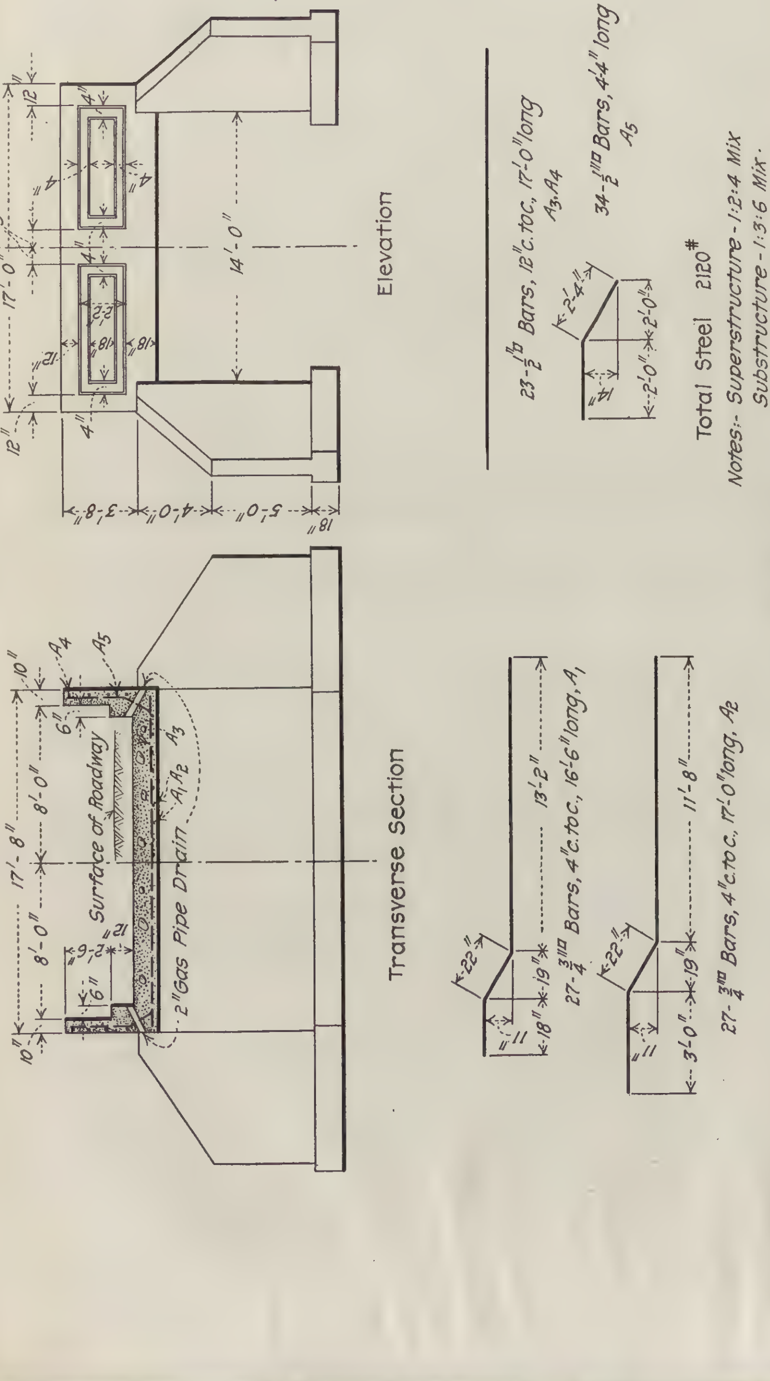


Fig. 38.—Concrete bridge of 14 ft. span and 16 ft. roadway. Designed by the Wisconsin State Highway Commission.

cut from 80 to 100 square feet per day of 8 hours or over, approximately 150 square feet of surface in like time.

132. Method of Estimating the Materials and Cost of Construction of a Concrete Highway Bridge.

Problem.

To replace an old wooden bridge with the reinforced-concrete bridge shown in Fig. 38.

Assumptions.

(1) Wooden bridge to be placed in temporary position at roadside for traffic during construction of new bridge.
(2) Wooden bridge has clear span of 14′–0″. Abutment and wing walls are of 6″ x 6″ piles with 2″ sheathing.
(3) Wing walls of wooden bridge located as per new design. (Roadway height to be unchanged.)

Location of Bridge.

(1) On public highway 5 miles from town or shipping point.
(2) One and one-half miles from a gravel pit.
(3) One-half mile from water supply.

Estimate of quantities.

(1) Excavation.

Area of A $= \frac{5.5+1.5}{2} \times 10 = 35$ sq. ft. (See Fig. 39a).

Length of excavation one side = total length of abutments and wing walls = 35 ft.

Volume excavation above footings both sides $= \frac{2 \times 35 \times 35}{27} = 90.5$ cu. yd.

Volume excavation of footings $= \frac{2 \times 3 \times 1.5 \times 35}{27} = 11.6$ cu. yd.

Total volume of excavation $= 90.5 + 11.6 = 100$ cu. yd.

Assume all excavation requires picking.
" ⅔ of excavation removed by drag scraper.
" ⅓ " " " " shovel.

Picking

$\frac{100}{3.5} = 28.6$ hrs. at 20c $5.70

Scraping for 50-ft. drag.

$\frac{2}{3} \times \frac{100}{5} = 13.2$ hrs. at 45c 5.95

Shovelling

$\frac{1}{3} \times \frac{100}{1.5} = 22$ hrs. at 20c 4.40

Total cost excavation $16.05

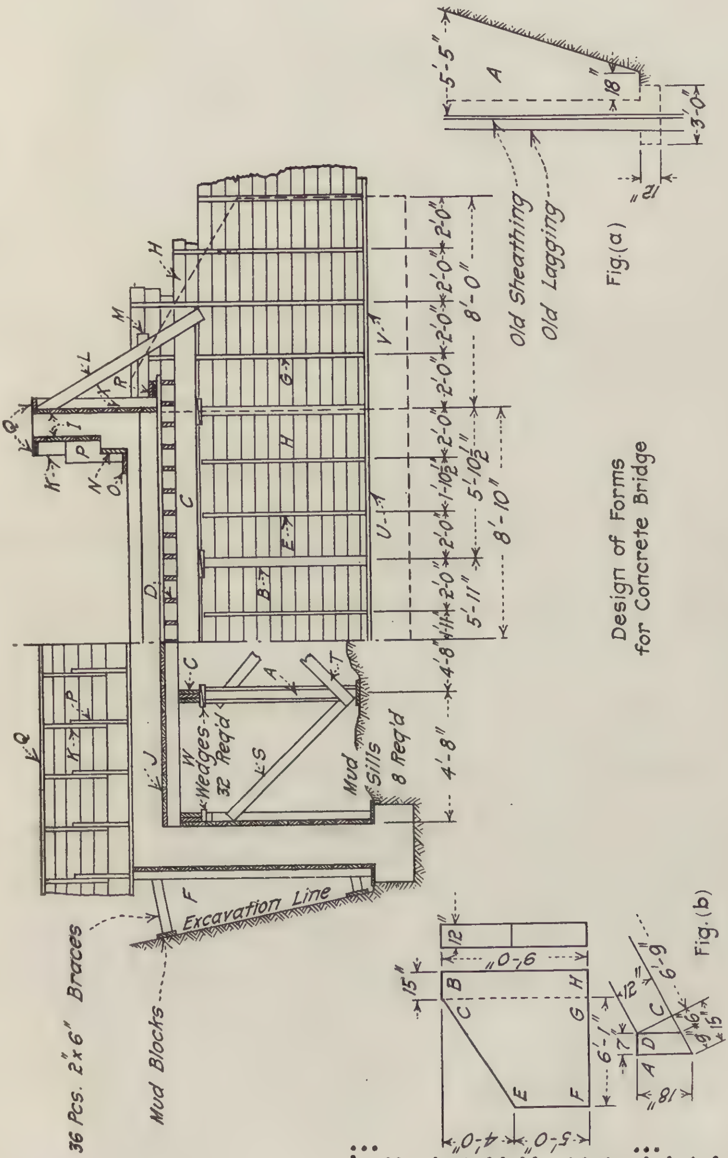

Design of Forms
for Concrete Bridge
Old Sheathing
Old Lagging
Fig.(a)
Fig.(b)
Excavation Line
Mud Blocks
36 Pcs. 2"x6" Braces
Wedges
32 Req'd
Mud
Sills
8 Req'd

FIG. 39.

(2) Volume of concrete and materials.

(a) For Superstructure

Slab $= 17\frac{2}{3} \times \frac{14}{12} \times 17 \times \frac{1}{27} = 13.00$ cu. yd. ....13.00 cu. yd.

Parapet walls $= 2\,(3.5' \times \frac{10''}{12} + \frac{6}{12} \times 1) \times 17 \times \frac{1}{27} = 4.27$ cu. yd.

Total concrete in superstructure........................17.27 cu. yd.

(b) For Substructure.

Abutments to footing $= 2\,(17.67' \times 8 \times \frac{18}{12}) \times \frac{1}{27} = 15.70$ cu. yd.

Wing Walls. (See Fig. 39b).

Volume C E F G $= \frac{(5+9)}{2} \times \frac{73}{12} \times 1 = 42.5$ cu. ft.

Area A B C D $= \frac{(18'' + 13.5'' \times 7'')}{2} + \left(\frac{6}{2} \times 12\right) = 146$ sq. in.

$\frac{146}{144} = 1.01$ sq. ft.

Volume $= 1.01 \times 9 = 9.1$ cu. ft.

Total volume concrete 4 wing walls $= 4 \times (42.5 + 9.1) \times \frac{1}{27} =$ 7.64 cu. yd.

Footings =

$$2 \times \frac{(17'\text{-}0'' + 8'\text{-}8'' + 8'\text{-}8'') + (19\text{-}5 + 6'\text{-}1'' + 6'\text{-}1'')}{2}$$

$$\times\, 3 \times 1.5 \times \frac{1}{27} = 11 \text{ cu. yd.}$$

Total concrete in substructure $= 15.70 + 7.64 + 11 = 34.34$ cu. yd.

TABLE VI.

Concrete Quantities.

	Cu. Yd. Concrete	Sacks Cement	Cu. Yd. Sand	Cu. Yd. Gravel
Superstructure..................	17.27	104.0	7.4	15.0
Substructure......................	34.34	173.5	16.0	32.0
Total......................	51.61	277.5	23.4	47.0

(3) Mixing and placing concrete.

(a) Mixing 52 cubic yards of concrete.

$52 \times \frac{3}{2} = 78$ hours.

(b) Placing $52 \times \frac{4}{3} = 69.3$ hours.

Total $= 78 + 69.3 = 147.3$ hrs. at 20c........................$29.46

(4) Steel Reinforcement

Generally the quantity of reinforcing bars is given on the plans submitted (See Fig. 38).

(5) Forms (Lumber and Erecting).

It is convenient to design the forms for the bridge in question so that the quantities of lumber can be easily taken from the plan. Since the forms must be sufficiently strong to carry the concrete it is necessary to figure the size of studs required. Table I, page 146 was used in figuring the size of studding.

Cost of Forms.

Cost of lumber 4,900 B. M. at $25 per M. B. M. charge 10%	$12.25
Cost of building and removing 4,900 B. M. at $20 per M. B. M.	98.00
Cost of nails, spikes, etc., $2 per M. B. M.	9.80
Total cost of forms	$120.05

(6) Hauling Charges.

(a) Moving to and from the job.

Equipment. Mixer, tool box, hand pump, wheelbarrows, scraper, 2 box tank wagons.

Length of trip 10 miles.

$$\text{Time 1 trip} = \frac{5280 \times 10}{2{,}000} \times 10 = 4.4 \text{ hr.}$$

Assume 2 trips will move the equipment at 4.4 hr. = 8.8 hr.

Including time of loading 10 hr. would be required.

10 hr. at 45c	$4.50
Labor 1 man loading at 20c	2.00
1 Foreman at 40c	4.00
Hauling to job	10.50
Hauling from job	10.50
Total moving charge	$21.00

(b) Hauling Water.

52 cu. yd. concrete at 70 gal. per yd. = 3640 gal. required.

500 gal. or about 2 tons per load. Haul 1 mile.

$$\frac{3640}{500} = 8 \text{ loads of water.}$$

$$\text{Time of haul} = \frac{5280}{2000} \times \frac{10}{60} = 44 \text{ hr. per trip of 1 mile.}$$

Loading tank 1 hr. = 1.00.

Team time per load = 1.44.

Cost of hauling = 8 x 1.44 x 45c = $5.20.

(c) Hauling Materials.

Cement. Trip 10 miles = load 40 sacks.

$\frac{278}{40}$ sacks = 7 trips.

Team time = $\frac{7 \times 10 \times 5280}{2000} \times \frac{10}{60}$ = 30.8 hr.

Time loading = 1 yard man 1 driver.

$7 \times 40 \times \frac{3}{4} \times \frac{1}{2} \times \frac{1}{60}$ = 1.75 hr.

Unloading equal time = 1.75.

Total team hours = 30.8 + 1.75 + 1.75 = 34.3 hr.

Cost of hauling—team = 34.3 x 45c	$15.40
1 man unloading 1.75 hr. at 20c	0.35
Total cost of hauling cement	$15.75

Lumber and Steel. Lumber weighs 32 lb. per cu. ft.

$\frac{4900}{12}$ B. M. x 32 = 13000 lb.

Assuming 2 tons per load will require 3 trips, leaving 1000 lb. to be hauled with 2120 lb. of steel.

Cost of hauling 4 trips = $\frac{4 \times 5280 \times 10 \times 10}{2000 \times 60}$ at 45c = $7.92.

Loading and unloading requires ½ hr. each time 4 loads = 4 hr.

Loading 2 hr. at 45c	$.90
Unloading 2 hr. at 20c	.40
Unloading 2 hr. at 45c	.90
Loading and Unloading	$2.20
Total cost of hauling = $7.92 + 2.20 =	$10.12
Hauling lumber away from job, 3 trips = $10.12 x ¾	7.55
Total	$17.67

Aggregates.

Required sand 23.4 cu. yd. + 10% = 26 cu. yd.

Required gravel 52.0 cu. yd. + 10% = 52 cu. yd.

Sand wagon load 1.3 cu. yd. = trip 3 miles.

No. trips $\frac{26}{1.3}$ = 20.

Hauling cost $\frac{20 \times 3 \times 5280 \times 10}{2000 \times 60}$ = 26.4 hr. at 45c	$11.88
Loading 2 men (driver and pit man) load 6 yd. 1 hr.	
$20 \times \frac{1.32}{6}$ = 4.40 at 45c	1.98
4.44 at 20c	.88
Unloading $20 \times \frac{5}{60}$ at 45c	.75
Total	$15.49

Gravel.

$\frac{52}{1.3}$ yd. = 40 trips.

$\frac{40 \times 3 \times 5280 \times 10}{2000 \times 60}$ = 52.8 hr. at 45c $23.76

Loading 2 men (driver and pit man)

$40 \times \frac{1.3}{5}$ = 10.4 hr. at 45c 4.75

1 laborer = 10.4 hr. at 20c 2.08

Unloading = $40 \times \frac{5}{60}$ = 3.3 at 45c 1.49

Total $32.07

(7) Screening Aggregates at Pit.

Assume that 100 cu. yd. of bank-run will have to be screened to obtain the necessary quantity of sand and gravel.

$\frac{100}{2.5}$ x 20c = $8.00.

Back filling excavation and clearing premises.

1 team, 1 day at $4.50 .... $4.50
1 man, 1 day at $2.00 .... 2.00

Total $6.50

(8) Miscellaneous Costs.

Loss on and care of cement sacks 70 bbl. at 10c	$7.00
Galvanized iron pipes for drains ¾″ 30′ at 8c	2.40
Oil and gas for mixer engine	3.50
Depreciation of equipment of $300 at 0.17% per day of 6 days on the job	3.06
Employers liability insurance	5.00
Total Miscellaneous items	$20.96

SUMMARY OF ESTIMATE

Net cost of materials:

Cement 70 bbl. at $1.60 net	$112.00	
Sand / Gravel 100 cu. yd. at 25c	25.00	
Steel Reinforcement 2120 lb. at 2.2c	46.64	
Water	10.00	
		$193.64
Cost of forms		120.05
Excavation		16.05
Concrete mixing and placing		29.46

Hauling Charges:		
Moving to and from job	$21.00	
Hauling Water	5.20	
Hauling Cement	15.75	
Hauling Sand	15.49	
Hauling Gravel	32.08	
Hauling lumber and steel	17.67	
		$107.19
Screening Aggregates		8.00
Back filling and clearing premises		6.50
Miscellaneous		20.96
		$501.85
Add 5% for contingencies		25.00
Profit 20%		100.00
Total estimated cost of bridge		$626.85

133. Conclusion.—The intent of this lesson is primarily to inform the student in the art of estimating the quantities of materials used in and the cost of proposed work; incidentally to teach common-sense management of construction because it would be useless to estimate scientifically and then to construct in a haphazard way.

The estimator must picture the construction to completion while estimating. Not only is it necessary to see it, but the planning of the work should be recorded and every problem solved at least in a general way, so that such plan can be carried out in practice. The student may be disappointed at not finding herein many cost figures to which he could refer when estimating. Cost figures representing the experiences of others are most dangerous when blindly accepted by the inexperienced because they represent the practice of experienced builders, and rarely or never are accompanied by methods used.

If the student once learns the method of estimating, he will find that only little actual experience is necessary to enable him to estimate the time taken by men or teams to do certain work.

BILL OF LUMBER FOR FORMS.

	Number Pieces	Dimensions (Inches)	Length (Feet)	B. M.	Where Used
A	8	4″ x 4″	5′–6″	58.6	Intermediate Posts
B	8	4 x 4	6–0	64.0	Posts at abutments
C ..	10	2 x 10	26–0	433.3	Beams
D	27	2 x 6	13–6	365.0	Joists
E	12	2 x 4	6–0	48.0	Lagging abutments
F	20	2 x 4	9–0	120.0	Lagging abutments
G	32	2 x 4	9–0	192.0	Lagging wing walls
H	....	2 x 6	....	1145.0	Sheathing abutments
I	24	2 x 6	18–0	432.0	Sheathing parapets
J	28	2 x 6	22–0	616.0	Flooring
K	20	2 x 6	2–6	50.0	Parapet bracing
L	8	2 x 6	7–0	56.0	Parapet bracing
M	8	2 x 6	3–0	24.0	Parapet bracing
N	2	2 x 12	18–0	72.0	Parapet
O	2	2 x 10	18–0	60.0	Parapet
P	20	2 x 12	2–6	100.0	Parapet bracing
Q	4	2 x 6	18–0	72.0	Parapet bracing
R	4	2 x 6	16–0	64.0	Parapet bracing
S	12	2 x 6	7–0	84.0	Post cross bracing
T	8	2 x 6	7–0	56.0	Post cross bracing
U	4	2 x 10	18–0	120.0	Abutment sills
V	8	2 x 10	8–6	113.3	Wing wall sills
W	1	4 x 4	16–0	21.3	For 32 wedges
X	20	2 x 6	4–6	90.0	Parapet lagging

Actual..4456.5 B. M.
Add 10 %.. 445

Total..4900. B. M.

Examination Questions

56. Given the detailed plans and specifications for a concrete job, requiring excavation, forms and reinforcing steel, describe briefly how you would estimate the cost of the work so as to make a bid for the construction.

57. Suppose there are 100 cubic yards of concrete to be used in a job. How much money could be saved in labor by using a concrete mixer instead of mixing with shovels, if the workmen receive 25 cents per hour and the mixer charge for depreciation, oil, etc., is estimated at 30 cents per cubic yard of concrete?

58. If you were asked the approximate cost of building a wall 150 feet long, 12 inches thick and 14 feet high, 4 feet of this wall to be in the ground and a footing 2′ 0″ wide and 1′ 0″ deep the full length of the wall, how would you figure the approximate cost?

59. When, with respect to length of haul, is it more economical to use wheel scrapers than drag scrapers?
60. There are to be 50 yards of gravel and 25 yards of sand unloaded from cars on a railroad siding and hauled 5 miles over good, hard road, ordinary grade in dump wagons. Teams and driver cost 50 cents per hour and labor 25 cents per hour. What will it cost to get the material from the cars to the job?
61. How much should be added to the net price of cement per barrel for sack charges?